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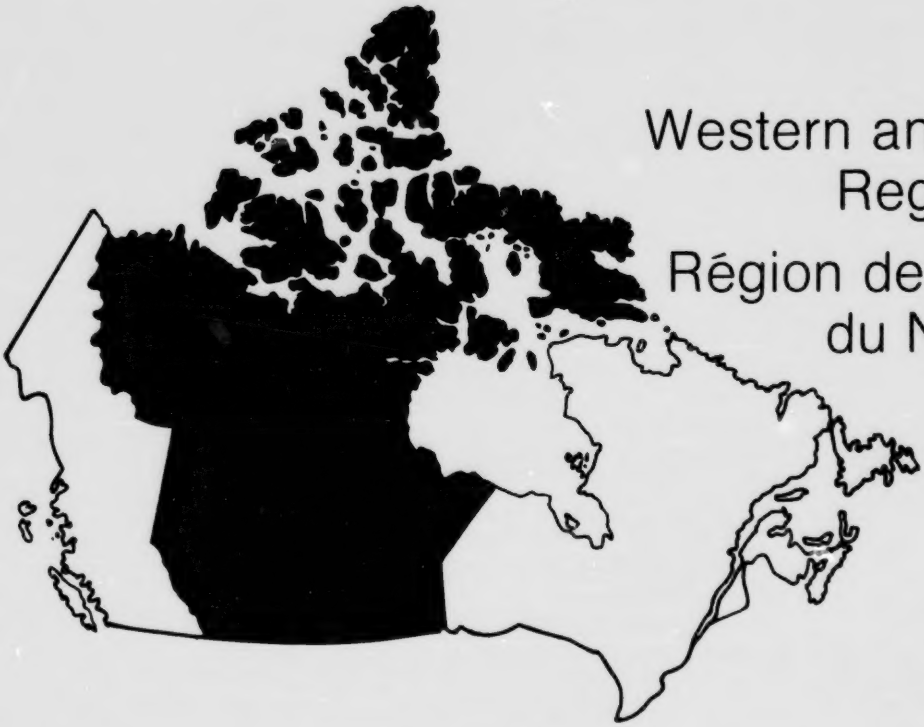

Western and Northern Region

Région de l'Ouest et du Nord

Environmental Protection Service

Service de la protection de l'environnement

SKM Consulting Ltd.

REVIEW AND ASSESSMENT
OF
CURRENT FLARING TECHNOLOGY

REPORT CP(EP) WNR-87/88-5

REVIEW AND ASSESSMENT OF CURRENT FLARING TECHNOLOGY

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for:

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in association with
Government Industry Consultative Commmittee on Flaring (GICCOF)

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Government Industry Consultative Committee on Flaring
(GICCOF)

This committee is comprised of the following organizations:

- Alberta Environment
- Alberta Energy Resources Conservation Board
- Environment Canada
- Alberta Oil Sands Technology and Research Authority
- Canadian Petroleum Association
- Independent Petroleum Association of Canada
- Alberta Oil Sands Industry Environmental Association
- Petroleum Association for Conservation of the Environment
- Canadian Chemical Producers Association
- Canadian Gas Processors Suppliers Association

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1.0 SUMMARY

The production and processing of hydrocarbons, petrochemicals, fertilizers and other products of the processing industries necessitates the atmospheric disposal of waste gases on a continuous and/or intermittent basis. Disposal of these gases must be done in a safe, economical and environmentally acceptable manner. Flare systems are widely employed for this purpose since the combustion process converts flammable, toxic and/or corrosive gases into non- or less-objectionable compounds. In addition, the heat released by the combustion assists in the dispersion of any air contaminants in the combustion products, such as sulfur dioxide.

There are many different types of flares, which may be grouped in the two general categories of elevated flares (the most common) and ground flares. In each general category are found standard non-smokeless utility flares, assisted smokeless flares and staged multi-point smokeless flares.

The evolution of flare system technology has progressed from the rudimentary open pipe ignited by burning arrows, Very pistols or shotguns, etc., in response to various safety, economic and environmental considerations. A primary concern is to keep the flare burning and this led to flame retention devices to prevent liftoff and/or blowout, continuous burning pilots with windshields and reliable remotely initiated ignition systems. The hazards of radiation and liquid carry-over led to height and location criteria, and provision of adequate liquid knockout facilities.

Safety concerns also prompted the adoption of liquid seals and the use of adequate purge gas to prevent flashback. Economic incentives then led to the development of purge reduction seals, and to the modification of flare tips to prevent damage at low purge gas flows.

1.0 Summary (cont'd)

Environmental concerns prompted the development of smokeless flares. Initially developed smokeless flares were of the assisted type, utilizing various means to induce additional combustion air: steam, water, high pressure gas and low pressure air. More sophisticated designs evolved to reduce noise levels, particularly for steam assisted flares.

A more recent development is the staged multi-point flare, which provides smokeless combustion and lower radiation levels without external assist, by utilizing the energy of the waste gas to provide mixing and disperse the gas into the combustion air. The enclosed ground flare, utilizing this concept, provides invisible as well as smokeless combustion.

The performance of flare systems with respect to most safety, environmental and economic criteria, such as smoke, noise, visibility, radiation, etc., is readily observable and assessed. These assessments are outlined in Tables 1.1 and 1.2 for sweet gas and sour gas, respectively. It should be noted that each performance objective is treated entirely separately, and the best means of achieving it is outlined. In an actual design case involving a number of performance objectives, the more rigorous requirements will govern.

Generally speaking the best available technology is proven technology that will best meet the performance objective without regard for economics. The best practical technology is proven technology that takes into account economic considerations, generally on the basis that an intermittent flare will operate at more than 25 percent of its maximum capacity only a small percentage of the time. Where more than one technology will equally meet a performance objective, the lowest cost one is outlined in the tables.

1.0 Summary (cont'd)

Of primary concern in recent years is the one aspect of flare performance that is the most difficult to definitively assess, that of combustion efficiency. Since 1979 a number of significant flare combustion efficiency studies have been conducted, the most extensive of which has been the EPA/EER studies conducted by Energy and Environmental Research Corp. for the U.S. Environmental Protection Agency. This pilot flare study, which was conducted over a number of years, has recently been concluded. The major conclusion of the study is that a flare operated with a stable flame (i.e. the flame is maintained) will exhibit combustion efficiencies exceeding 98-99%. This finding is in general agreement with previous pilot studies, however verifying these efficiencies for full scale industrial flares remains a formidable task. Uncertainties as to the effects of winds, control system variations on intermittent flares, and scale-up considerations remain to be resolved.

The techniques currently available for direct sampling of industrial flare plumes under wind conditions permit the measurement of local combustion efficiencies only, rather than the overall combustion efficiency. The remote sensing of flare emissions is a possible alternative to direct sampling, but instrumentation and techniques for this purpose are as yet undeveloped.

To illustrate the effect upon capital and operating costs of the non-smokeless utility flare vs the various smokeless varieties, designs and cost estimates for flare systems were prepared for hypothetical typical large, medium and small gas processing plants with a central Alberta location. Both elevated and ground flare estimates are included although the latter is normally suitable for sweet gas only. Also included are estimates for small oil battery flare systems. Summaries of the capital and operating cost data are shown on Tables 1.3 and 1.4, respectively. Costs are in March 1987, Canadian dollars.

1.0 Summary (cont'd)

It should be noted that flares at gas processing plants are normally in use on an intermittent basis, as opposed to continuous low flow rate flares which are more commonly found at chemical plants, or at oil production batteries where small quantities of solution gas are flared. Gas processing plant flares must be designed to handle maximum emergency releases which may be many times the flow rates of the more normally encountered releases. Since these maximum emergency releases occur very infrequently, the capital and operating costs of providing for smokeless operation to 100% of capacity would be excessive, particularly for the assisted type flares. Hence it is typical to design such flares for smokeless operation to a fraction of maximum capacity. Hence all the elevated smokeless flare costs are based on smokeless operation to 25% of capacity. These costs are on the same basis, and can be compared to the combination ground and utility flare cases. Cost estimates for smokeless flares at 100% of relief capacity were done only for the staged multi-point ground flares.

The current regulatory practices in various U.S. jurisdictions were reviewed and compared with Alberta's regulatory requirements respecting flares. Generally, all of the jurisdictions reviewed require smokeless operation of flares, commonly defined by a basic visible emissions opacity limit of 20%, except for Illinois at 30% and Alberta at 40%. New continuous flares (not emergency) in all U.S. jurisdictions are required by EPA regulations to provide for a continuous flame and pilot flame monitoring. Most U.S. jurisdictions, as well as Alberta, apply these requirements to all flares.

Minimum heat contents of the flared gases, which are required throughout the U.S. for new continuous flares, and in Texas for all flares, are comparable to Alberta requirements. Maximum ground level sulfur dioxide concentration limitations are generally more stringent in Alberta than in the U.S. jurisdictions citing these requirements (Bay Area of California, Texas and Illinois).

1.0 Summary (cont'd)

Maximum allowable ground level concentrations of hydrogen sulfide appear to be lower in Alberta (0.01 ppm, 1 hr.) than in Texas (0.08/0.12 ppm, 1/2 hr.). Alberta requirements regarding particulates ground level concentrations (60 mmg/m^3, annual) appear to be somewhat more stringent than those of Illinois (60/75 mmg/m^3, annual). The same observation also applies to CO and NO_2. Only Alberta stipulates maximum ground level concentrations for oxidants, and only Texas stipulates a minimum destruction efficiency for flares.

TABLE 1.1 TECHNOLOGY ASSESSMENTS SWEET GAS

Performance Objective	Best Available Technolgy (B.A.T.)	Best Practical Technolgy (B.P.T.)
Environmental:		
Smokeless (1)	Staged multi-point open ground flare	25% as in B.A.T. (2) 75% Elevated utility (3) flare
Low Noise	Utility flare	Utility flare
Low Visibility	Enclosed ground flare	25% as in B.A.T. (2) 75% Elevated utility (3) flare
Safety:		
No explosive mixture in flare system	Liquid seal plus density seal	Velocity seal
Low radiation	Enclosed ground flare	25% as in B.A.T. (2) 75% Elevated utility (3) flare
No liquid carryover	Liquid knockout plus remote location	As in B.A.T.
Dispersion of unignited gases	Elevated flare	Elevated flare
Reliability:		
Flame stability	Utility flare	Utility flare
Ignition systems	Continuous pilot Flame front ignition	As in B.A.T.
No burn-back or flame pulldown	Staged multi-point flare	Special design utility flare with velocity seal
Other:		
Minimum space requirement	Enclosed ground flare	Elevated flare

(1) Assumes smoking gases are flared.
(2) 25% of maximum emergency relief capacity.
(3) 75% of maximum emergency relief capacity.

TABLE 1.2 TECHNOLOGY ASSESSMENTS SOUR GAS

Performance Objective	Best Available Technolgy (B.A.T.)	Best Practical Technolgy (B.P.T.)
Environmental:		
Smokeless (1)	Staged multi-point elevated flare	25% as in B.A.T. (2) 75% Elevated utility (3) flare
Low Noise	Elevated utility flare	Elevated utility flare
Low Visibility	Elevated utility flare	Elevated utility flare
Safety:		
No explosive mixture in flare system	Liquid seal plus density seal	Velocity seal
Low radiation	Staged multi-point elevated flare	Elevated utility flare
No liquid carryover	Liquid knockout plus remote location	As in B.A.T.
Dispersion of unignited gases	Elevated flare	Elevated flare
Reliability:		
Flame stability	Elevated utility flare	Elevated utility flare
Ignition systems	Continuous pilot Flame front ignition	As in B.A.T.
No burn-back or flame pulldown	Elevated staged multi-point flare	Elevated special design utility flare with velocity seal
Other:		
Minimum space requirement	Elevated flare	Elevated flare

(1) Assumes smoking gases are flared.
(2) 25% of maximum emergency relief capacity.
(3) 75% of maximum emergency relief capacity.

TABLE 1.3

CAPITAL COSTS
$ X 1000
ELEVATED FLARES

Plant Size 10^6 SCFD	Plant Size $10^3m^3/d$	Utility	Steam Assist	Air Assist	Multi-Point	Staged Multi-point
350	9,911	1,290	1,518	1,657	1,523	1,720
80	2,265	396	478	527	479	550
20	566	144	171	188	172	196

GROUND FLARES (350 x 10^6 SCFD only)

	Open	Enclosed
Combination: 25% Staged Multi-point 75% Utility	1,769	3,636
100% Staged Multi-point	2,823	10,291

SMALL OIL BATTERY FLARES

Nominal Size	Capacity 10^6 SCFD	Capacity $10^3m^3/d$	Utility	Air Assist	Velocity Jet	Flare Tip Incinerator
4 inch	0.80	23	42.2	55.2	54.2	57.2
3 inch	0.45	13	36.6			
2 inch	0.05	1.4	30.9			

SCFD means Standard Cubic Feet per Day

TABLE 1.4

ANNUAL OPERATING COSTS
$ X 1000
ELEVATED FLARES

Plant Size 10^6 SCFD	Plant Size $10^3 m^3/d$	Utility	Steam Assist	Air Assist	Multi-Point	Staged Multi-point
350	9,911	80	125	119	91	100
80	2,265	25	37	36	29	33
20	566	9.4	12.9	12.8	10.8	12.0

GROUND FLARES (350 x 10^6 SCFD, Open only)

Combination, Staged Multi-point and Utility	108
100% Staged Multi-point	155

SMALL OIL BATTERY FLARES

Nominal Size	Utility	Air Assist	Velocity Jet	Flare Tip Incinerator
4 inch	2.9	4.5	3.8	3.7
3 inch	2.5			
2 inch	2.1			

2.0 INTRODUCTION

Flaring has been and remains the traditional means used to dispose of industrial relief gases. These gases comprise a complete range of hydrocarbons, sulfur compounds, and chemical releases. Hydrocarbons are estimated to be approximately 95% of the total gases flared. Major industries dependent on the use of flares include oil and gas production, petroleum refining, petrochemical processing and iron and steel production.

Two flare operating modes predominate in industry: an intermittent emergency release, and a more continuous low flow rate release. Emergency releases, in the process industries, result from process start-up or turn-around, and from major process upsets or power failures. Although major releases are infrequent, when entire process plant gas inventories must be released, such releases [in excess of 1 million pounds/hour (450 t/h)] can go to safe disposal through a flare.

Continuous low flow rate releases are more common in the chemical industry. These releases generally result from process vents, and fugitive, storage and secondary emission sources. Typically, these release rates can range from minor for fugitive type sources to moderately high for normal process venting. Continuous rate flaring, along with relatively minor emergency releases are the predominate operating mode for the major proportion of material flared. Alternatives to flaring, such as incineration or vapor recovery systems, exist for low flow rate releases, but these are generally impractical to build with sufficient capacity to handle massive emergency releases.

The widespread use of flares to dispose of industrial relief gases, and the effect these flares have on the environment have recently been of concern to regulatory agencies. As a result, a number of studies sponsored by both governmental agencies and industry have been conducted to evaluate the combustion characteristics of flaring. Of primary

2.0 Introduction (cont'd)

importance is the degree to which the flared materials are combusted. The completeness of combustion, or combustion efficiency as defined here, determines the ultimate impact flaring will have on the environment.

In early 1986, a Government Industry Consultative Committee on Flaring (GICCOF) was established by Alberta Environment in consultation with Environment Canada to assess flaring technology, operating practices and existing information on flare combustion. This committee reviewed several relevant studies pertaining to sour gas flaring and felt that further investigation was necessary. It was further recognized by the committee that design and operating practices of various flaring operations in the industry should be documented and compared against the technology available through suppliers and designers. Consequently a two part study has been conducted, namely:

Part A - Review and Assessment of Current Flaring Technology

Part B - Summary of Current Oil and Gas Industry Flaring Practices

This report by SKM Consulting Ltd. presents the results of Part A of the two part study. The terms of reference of the Part A study are included in Appendix "C".

3.0 STUDY METHODOLOGY

The following sub-sections outline the methods by which the necessary input data on flaring technology and costs were acquired. This phase was followed by cost estimating, review and assessment, and report preparation.

3.1 Literature Review

The literature review included a review of information supplied by members of the GICCOF Technical Subcommittee, reports received from the U.S. Environmental Protection Agency on experimental work done for it on the subject of industrial flare efficiency, technical reports received from various flare equipment designer/manufacturers, and information available in SKM files.

Computer searches were also carried out for information published in recent years, aimed at identifying recently developed and/or emerging technologies, that are not at present commercially available. The following data bases were searched:

- TULSA (University of Tulsa)
- APILIT (American Petroleum Institute)
- COMPENDEX (Engineering Information Inc.)
- NTIS (National Technical Information Service - U.S. Department of Commerce)
- Ei ENGINEERING MEETINGS (Engineering Information Inc.)

The computer searches generated a total of 23 potentially relevant references of which 17 were obtained and reviewed. These are included in the total list of references shown in Section 10.0. The literature search did not reveal any recently developed and/or emerging flaring technologies. This is probably due, at least in part, to the fact that, historically, the development of flaring technology has been carried out

3.1 Literature Review (cont'd)

by the suppliers (designers and/or manufacturers) of this equipment. Any information on flaring technology currently being developed by the suppliers, but not yet commercially available, would not normally be published.

3.2 Supplier Survey

A list of 22 potential suppliers (designers and/or manufacturers) of flaring equipment was compiled from equipment buyer guides and other in-house information. These potential suppliers were all contacted by telephone and a total of 14 were identified as designers/suppliers of flare equipment (as opposed to heaters, boilers and other thermal equipment). Two were identified as fabricators only. Catalogue information was received from the following designers/suppliers.

Peabody Engineering Canada, Mississauga, Ont.	(1)
McGill Incorporated, Tulsa, Okla.	(1)
John Zink Company, Tulsa, Okla.	(1)
Flaregas Corporation, Spring Valley, N.Y.	(1)
National Air Oil Burner Co., Philadelphia, Pa.	(1)
Pilgrim Steel Company, Glassboro, N.J.	(1)
Hirt Combustion Engineers, Montebello, Calif.	(2)
Barber Industries, Calgary	(3)
Mactronic Systems Ltd., Red Deer	(4)
Polesystems Ltd., Calgary	(5)
Stettler Oilfield Manufacturing Ltd., Stettler	(6)
Westech Industrial Ltd., Calgary	(4)
Wells-Hall Ltd., Edmonton	(4)
Western Research, Calgary	(7)

Notes

(1) Complete flare systems
(2) Enclosed ground flares
(3) Pilots
(4) Ignition systems
(5) Stacks
(6) Pilots - complete small field flare systems.
(7) Waste gas incinerators

3.3 Supplier Inquiries

A detailed inquiry package was prepared to obtain budget cost information needed to prepare capital and operating cost estimates. The initial inquiry package was based on meeting the flaring requirements of a hypothetical typical large sour gas plant, utilizing five different elevated flaring systems with three different purge/sealing arrangements. Further inquiries were made for addendum pricing to enable cost estimates to be included for two types of ground flares. The inquiry package was submitted to six suppliers:

McGill
National Air Oil
John Zink
Flaregas
Peabody
Pilgrim

Detailed responses were received from McGill, NAO, and John Zink.

3.4 Review of Regulatory Practices

A review was made of information received by the GICCOF Technical Subcommittee from various U.S. jurisdictions, pertaining to current flaring regulatory requirements. This information was summarized and compared to Alberta regulations respecting flares.

4.0 GENERAL DESCRIPTION OF FLARING SYSTEMS

The production and processing of hydrocarbons, petrochemicals, fertilizers and other products of the processing industries necessitates the atmospheric disposal of waste gases on a continuous and/or intermittent basis. Disposal of these gases must be done in a safe, economical and environmentally acceptable manner.

Vent stack disposal can be the preferable method in certain instances where the gases are non-toxic and readily dispersible such as hydrogen and methane, or when the gas is non-combustible, such as carbon dioxide. However, flare systems are widely employed since the combustion process converts flammable, toxic and/or corrosive gases into non- or less-objectionable compounds. In addition, the heat released by the combustion assists in the dispersion of any air contaminants in the combustion products, such as sulfur dioxide.

There are many different types of flares which may be grouped in the two general categories of elevated flares and ground flares. The selection of the type of flare and its specific design features is influenced by many factors, including such considerations as:

- volume and composition of gases to be flared
- environmental and safety considerations
- availability of space
- economics

4.1 Flare System Considerations:

A more detailed listing of the items (in addition to flow rates and characteristics of the gases to be flared) which must be considered in order to establish the type of flare system, and its particular design features, is as follows:

Environmental:

- Permissible ground level concentrations of air contaminants
- Tolerance for smoke
- Noise impact
- Visual impact of flame

Safety:

- Explosive mixture in flare system
- Heat radiation hazard to personnel
- Liquid carryover ("burning rain")
- Dispersion of flammable and toxic gas if unignited

Availability of Space:

Reliability and Efficiency:

- Flame stability
- Ignition systems
- Materials of construction
- Burn-back and flame pulldown at the flare tip
- Moving parts

Availability of Supporting Utilities:

- Steam
- High pressure gas
- Electric power
- Water for injection
- Purge gas
- Fuel gas

Economics:

- Capital costs
- Operating costs

Climatic Conditions:

- Wind velocities and pressures
- Ambient temperatures

4.2 Flare System Requirements:

The environmental constraints referred to in the previous section are met primarily by design criteria and sizing. Maximum ground level concentrations of complete combustion contaminants, such as SO_2, are achieved by sufficient flare height (normally elevated flares are used in such instances). Maximum combustion and destruction efficiencies are aimed for by designing to maintain flame stability (exit gas velocity and gas heating value limitations, flame holding devices) and by design configurations to promote good mixing of air and flare gases.

Smokeless burning of flared gases is achieved by a number of techniques, which are discussed in greater detail in the following sections. Noise levels can be minimized by various design techniques. The flame, in the case of ground flares, can be made invisible by enclosing it in a vertical shell structure which may be of a cylindrical, rectangular, or multi-sided shape.

In the area of safety concerns, the prevention of an explosive mixture occurring in the flare system is achieved by the use of purge gas, alone or combined with a sealing system as further defined in the following sections. The prevention of radiation hazards, and the potential hazards posed by the accumulation of flammable and/or toxic gases should the flare become unignited, is achieved by proper location and/or adequate height of the flare. The potential hazard of liquid carryover is addressed by the installation of adequate liquid separation facilities, and also by siting the flare such that it is not in close proximity to other facilities or personnel.

Flame stability is achieved by exit velocity and gas heating value limitations and by the design configuration of the flare tip and its flame retention device. The reliability of the flare pilots and ignition systems is an important consideration, which is discussed in greater detail in the following sections.

The top, say 8 to 12 feet (2.5 to 3.7 m), of the flare stack, which contains the flare burner, is known as the flare tip. The flare tip is normally fabricated of a high temperature alloy such as stainless steel. It is nevertheless subject to deterioration at low flaring rates due to "burn-back" and "flame pulldown". Burn-back occurs at very low exit velocities, when only the purge gas is being flared, and the flame moves down inside the flare tip. Flame pulldown occurs at higher, but still relatively low flaring rates, in moderate to high wind conditions. The formation of a low pressure zone on the downwind side of the flare tip causes the flame to lick down and impinge on the outside of the flare tip. Refractory lining is used in some designs on the inside and/or the outside of the flare tip to mitigate the effects of this flame impingement. Special design configurations inside the flare tip are used to prevent or minimize burn-back. Various types of windshields on the outside of the flare tip are used to minimize or mitigate the effects of flame pulldown. Staged, multi-point flare systems, which are described in the following sections are virtually free from deterioration due to burn-back or flame pulldown.

4.3 Elevated Flares:

The most common type of flare system currently in use is the elevated flare system. There are a number of reasons for this. Generally speaking, ground flares require more space and/or greater separation distances from other facilities due to thermal radiation considerations. This does not apply to enclosed ground flares, but the cost of the enclosure can be substantial.

In addition, the ground level flaring (without a tall enclosure) of gases containing toxic contaminants such as hydrogen sulfide would normally be unacceptable from an environmental point of view, and/or would pose a safety hazard to facilities personnel and the general public should the flare become unignited.

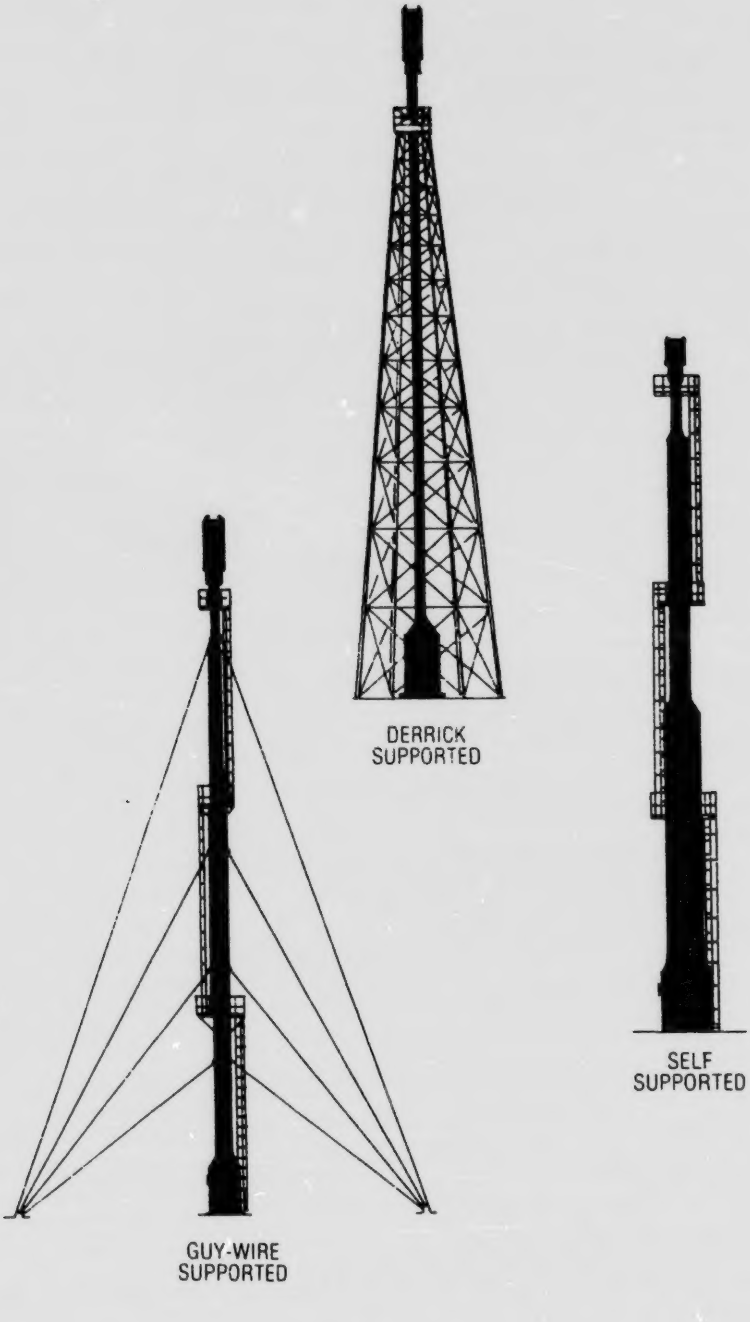

DERRICK SUPPORTED
SELF SUPPORTED
GUY-WIRE SUPPORTED

Figure 4.1

FLARE SUPPORT STRUCTURES

(Source: McGill Incorporated)

Structural support for elevated flare stacks is generally accomplished by one of three methods: guy-wire supported, self supported, and derrick supported. These are illustrated in Figure 4.1.

The guy-wire supported system is the least expensive to construct, and the most common in onshore oil and gas production facilities, but requires a radius around the flare stack approximately equal to the height of the stack for guy-wire anchor points.

The self-supported system requires only the land area necessary for the foundation, but the sections of the flare riser are normally larger in diameter than required for the guy-wire supported system, so the self-supported system is more expensive. The self-supported system also has a practical height limit of 250 feet (76 m) [guy-wire supported flare stacks have been constructed to 600 feet (183 m)].

The flare riser for the derrick-supported system is very similar to the riser of the guy-wire supported system; however, instead of support from guy-wires, there is a structural member or pipe fabricated derrick-support structure. Because of this structure, the derrick-supported system is also more expensive than the guy-wire supported system, and there is also a great deal of field labor required to erect the derrick. Derrick-supported flare systems are limited to a height of about 500 feet (152 m).

The following subsections discuss the various types of flares which are applicable in the case of elevated flaring systems. Most are also applicable in the case of ground flares.

4.3.1 Utility Flares

This flare uses the standard non-smokeless single point flare tip, and represents the majority of flare tips now in service. It is used when the gases being flared do not smoke, such as methane, ammonia, hydrogen, carbon monoxide, hydrogen sulfide, or where there is no requirement for the flare to be smokeless. A typical utility flare tip is shown in Figure 4.2.

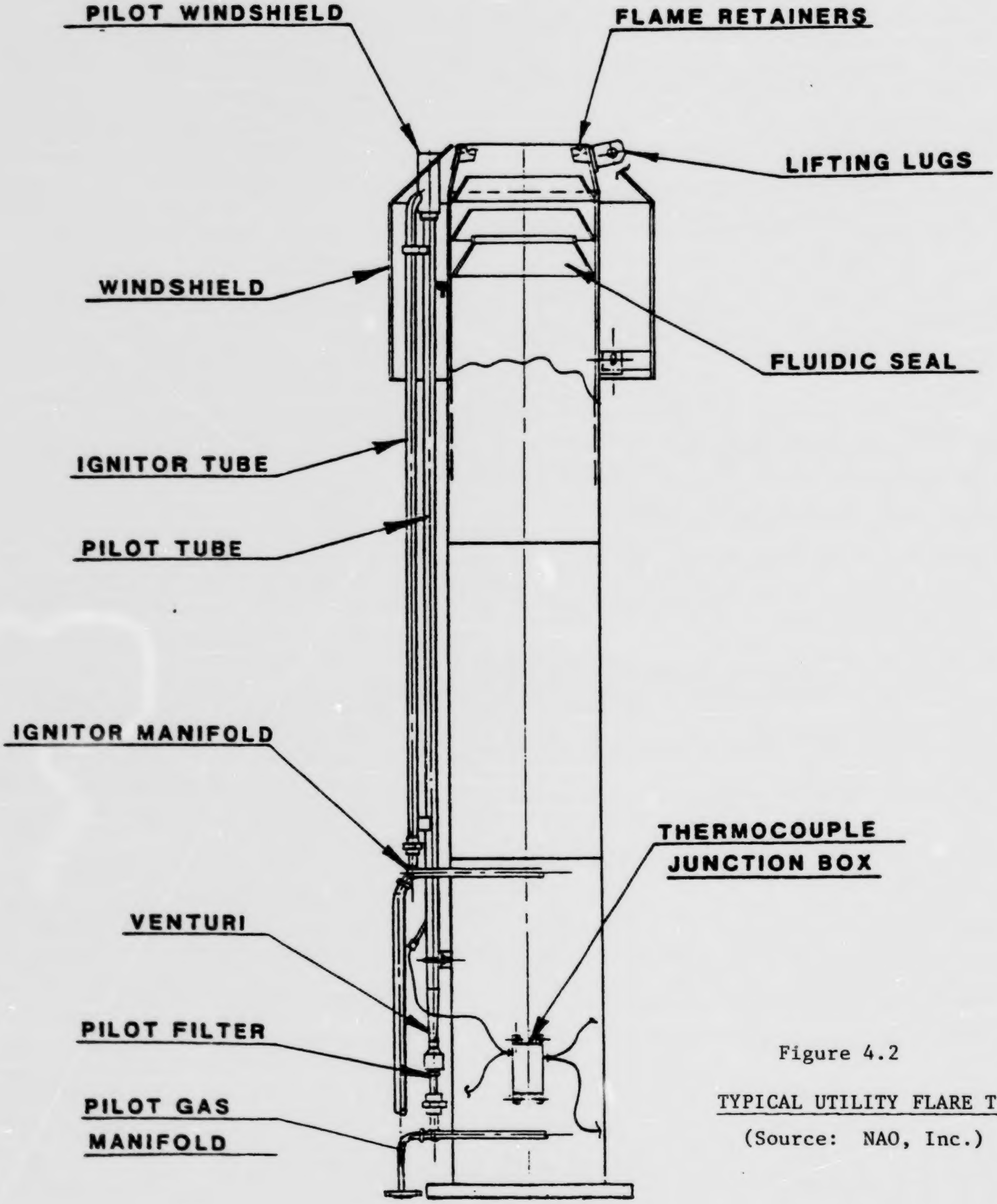

PILOT WINDSHIELD
FLAME RETAINERS
LIFTING LUGS
WINDSHIELD
FLUIDIC SEAL
IGNITOR TUBE
PILOT TUBE
IGNITOR MANIFOLD
THERMOCOUPLE
JUNCTION BOX
VENTURI
PILOT FILTER
PILOT GAS
MANIFOLD

Figure 4.2

TYPICAL UTILITY FLARE TIP

(Source: NAO, Inc.)

The flare tip will normally require at least one pilot with the number of pilots increasing as the diameter of the flare tip increases. The pilot(s) will normally be continuously burning and equipped with an ignition system.

The flare tip will be provided with a flame retainer or stabilizer, of a ring or vane type. A perforated or slotted ring welded to the outlet end of the flare tip creates a low pressure area around the periphery of the flare tip and "holds" the flame onto the tip. This permits a higher exit velocity without flame liftoff. The same result is achieved by a series of angled vanes welded to the outlet end of the flare tip, which creates a swirling action in the exit gases.

The flare tip will be constructed of a high temperature alloy such as stainless steel. In addition the larger diameter flare tips will be equipped with a windshield to minimize the attachment of the flame to the flare tip in the low pressure zone created on the downwind side, or an outer refractory coating to mitigate the effects of the flame attachment. The larger diameter (24 inch, 610 mm or over) may also be equipped with an inner refractory lining to protect the upper portion of the metal flare tip from damage due to internal burning.

4.3.2 Steam Assisted Flares

The injection of medium to high pressure steam (typically 75 to 100 psig, 520 to 690 kPag) into the gases being flared is a widely used method of preventing smoke. The steam is injected by means of a steam ring to which are attached multiple steam nozzles, which are located around the periphery of the outlet end of the flare tip and just above it. Larger diameter flare tips may also include nozzles injecting steam into the centre of the gas stream, just below the outlet end of the flare tip. More complex configurations involving additional steam rings and centre steam injection distributors are used in designs for low noise levels.

At least one designer/manufacturer uses the Coanda effect to inspirate air in with the injected steam, to pre-mix them with the flared gas stream, resulting in good efficiency and low noise levels. However, special precautions must be taken against plugging of the narrow steam slots. The flare tip design will otherwise be the same as that previously described for the utility flare. A typical steam assisted flare tip is shown in Figure 4.3.

Saturated steam is preferred to the use of superheated steam because it is somewhat lower in noise level. The quantity of steam required to prevent smoking varies with the composition of the gases being flared, however typical steam to flared gas mass ratios might range between 0.15 to 1 and 0.5 to 1. Excessive steam to flared gas ratios can have a detrimental effect on combustion efficiency.

The effects of steam injection on the combustion mechanism are believed to be as follows:

- the injection of steam provides turbulence, promotes mixing and inspirates air into the combustion zone all of which improves the combustion.
- steam serves as a catalyst to promote the completion of the combustion reactions.
- steam serves as a coolant and thus prevents the high temperature cracking of unsaturated or higher molecular weight saturated hydrocarbons with the resultant formation of free carbon (smoke).

The chief drawback to the use of steam injection is that it is not a practical option for those facilities without steam generation and distribution systems. This is the case for a large portion of the facilities requiring flare systems, particularly in oil and gas production. Further, even for those facilities with existing steam systems, the use of a steam assisted flare can impose a large additional load, albeit intermittent and infrequent, which

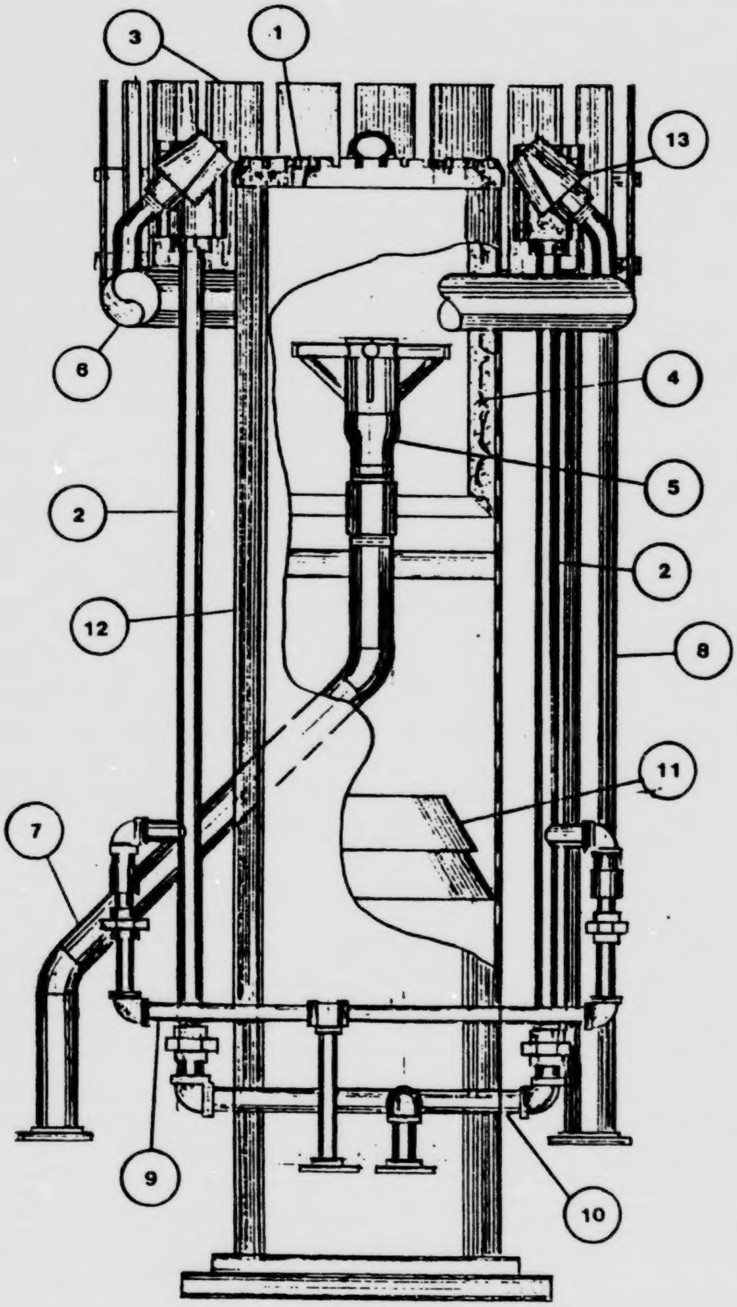


Figure 4.3

TYPICAL STEAM ASSISTED FLARE TIP

(Source: Pilgrim Steel Company)

NO.	DESCRIPTION
1.	FLAME HOLDER
2.	PILOT IGNITOR ASS'Y
3.	FLARE WINDSHIELD
4.	REFRACTORY (FOR FLARE SIZES 24" AND ABOVE)
5.	MULTI—PORT CENTER STEAM NOZZLE
6.	STEAM RING W/ STEAM NOZZLES
7.	CENTER STEAM RISER
8.	STEAM RING RISER
9.	PILOT GAS MANIFOLD
10.	FLAME FRONT MANIFOLD
11.	FLARE SEAL (OPTIONAL)
12.	FLARE MAIN BODY
13.	REDUCING CONES FOR ENTRAINMENT OF AIR & NOISE REDUCTION

may result in the need for more steam generation capacity. It also has a disproportionately larger effect on the boiler feed water make-up requirements, since the steam is lost to the atmosphere instead of being condensed and returned to the boiler. Hence the additional capital costs of a steam assisted flare vs a utility flare can be significant.

Another concern regarding steam injection, discussed in greater detail below in the section on control systems, is the difficulty in maintaining the proper steam to flared gas ratios in intermittent flares.

4.3.3 Water Assisted Flares

Water injection into the gases being flared can also be an effective method of controlling smoking. The water is injected through multiple spray nozzles located around the periphery of the outlet end of the flare tip and/or in the centre, in a similar arrangement to that of the steam injected flare tip. The flare tip design will otherwise be the same as that of the utility flare. Provided there is an adequate supply of fresh water (not always the case at oil and gas production facilities), the capital cost of water supply facilities should be somewhat less than that of steam supply facilities although the quantities of water required are significantly greater. The effects of water injection on the combustion mechanism are essentially the same as the effects of steam injection.

There are, however, a number of disadvantages to water assisted flares which have resulted in their not being widely used, the foremost of which would essentially preclude Canadian installations. These are as follows:

- the potential for freezing problems essentially limits water injection to locations which do not experience sub-freezing temperatures,

- at low flare gas flow rates it can be difficult to inject sufficient water to control smoking without extinguishing the flame. Maintenance of good combustion efficiency, even if the flame is not extinguished, is questionable.
- even at low wind conditions it is difficult to keep the flame within the area sprayed by the water nozzles. Hence the maximum smokeless capacity is limited to a relatively low value.
- it is difficult to completely vaporize the water and avoid the problem of water fallout, since the water droplets are retained in the flame envelope for a very short time.

4.3.4 High Pressure Gas Assisted Flares

The injection of high pressure gas into the flared gases can also be used to control smoking. The gas is injected through multiple nozzles located around the periphery of the outlet end of the flare tip and/or in the centre, in a similar arrangement to that of the steam injected flare tip. Other features of the design will be the same as those of the utility flare. The injection of high pressure gas provides turbulence, promotes mixing and inspirates air into the combustion zone, all of which improve the combustion. The amount of high pressure gas required is dependent on its pressure. At 100 psig (690 kPag) the ratio of standard volumes (SCF/SCF) of power gas to flared gas is about one to three.

High pressure air is the most effective gas to inject but would normally have the disadvantage of being the most expensive, particularly in terms of capital cost. High pressure hydrocarbon gases such as natural gas and fuel gas are also effective in controlling smoking, but they are also expensive. An intermittent flare at a natural gas processing plant, injecting high pressure natural gas, would probably represent the least expensive application for this method of smoke suppression, since the gas is available at high pressure without compression, and its cost would be lower than it would be at other facilities such as refineries and petrochemical plants. However, this cost will normally be significantly greater than the cost of steam.

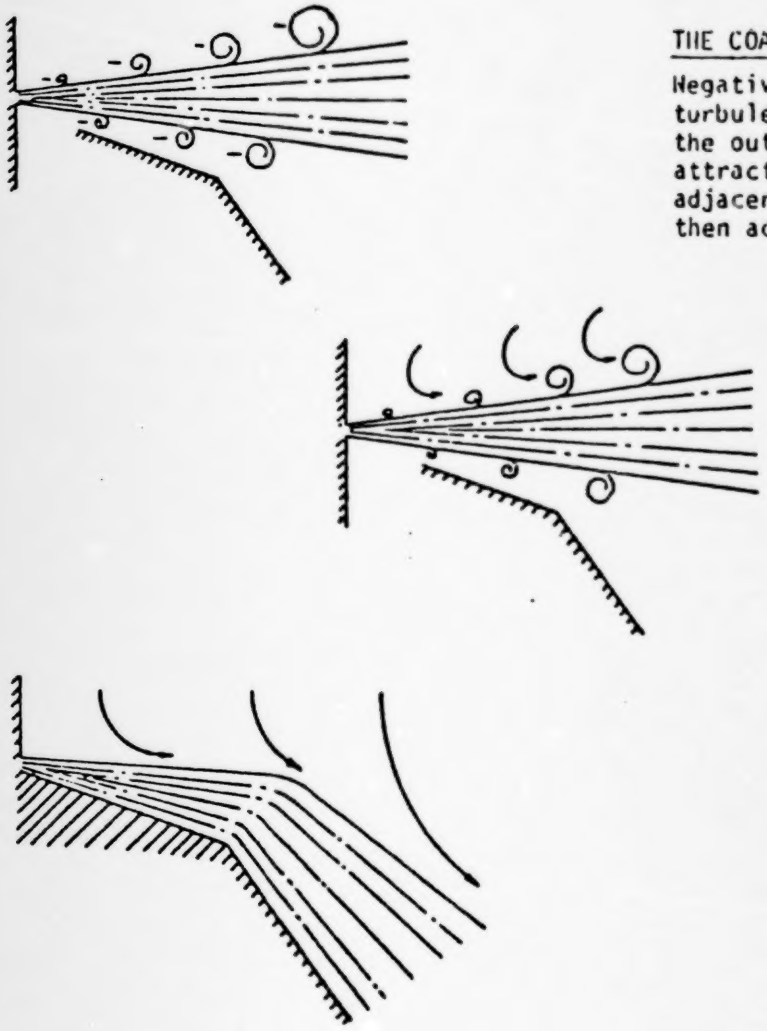
This type of flare tip, using natural gas or fuel gas can also be used to flare a waste gas that does not have sufficient heating value to sustain combustion on its own. A normally accepted minimum lower heating value required to sustain combustion is 150 BTU/SCF (5.6 MJ/m^3)(503). However, this minimum value can be independently affected by gas composition (see Section 8.3), and regulatory requirements (see Section 9.0) are in the 200 to 300 BTU/SCF (7.5 to 11.2 MJ/m^3) range.

A special type of high pressure gas assisted flare tip(1) utilizes the Coanda effect to smokelessly flare a low pressure gas using high pressure gas at about 20 to 30 psig (140 to 210 kPag). The flare tip is tulip shaped and utilizes a skin adhesion effect discovered by Henri Coanda (hence the "Coanda effect"). This is illustrated in Figure 4.4.

The high and low pressure gases flow concentrically to the flare tip with the high pressure gas in the annulus. The high pressure gas is ejected at sonic velocity through a slot orifice at the base of the "tulip". Due to the Coanda effect it clings to the surface of the "tulip" and forms a hollow cylinder around it. This change of direction entrains large volumes of air and causes turbulence which ensures good mixing of air with the low pressure gas leaving the inside of the "tulip", resulting in smokeless combustion.

However, there are a number of disadvantages which limit its applicability. The minimum ratio of high pressure to low pressure gas required is approximately three to one. This is significantly higher than the requirements of a conventional high pressure gas assisted flare. Further, the turndown is limited. With a fixed

(1) "Indair" flare tip; Craufurd Flares International Ltd.



THE COANDA EFFECT

Negative zones caused by turbulent eddies around the outside of the jet stream attract the fluid towards the adjacent wall to which it then adheres.

Opposing eddies and the deflection of the jet stream cause an inrush of ambient fluid (air)

Figure 4.4

THE COANDA EFFECT

slot orifice the turndown is two to one. With a variable slot orifice the turndown is improved, but only to four to one. This means that a substantial minimum quantity of high pressure gas would be required even at low flow rates of low pressure gas. Also, since the pilots ignite the high pressure gas which in turn ignites the low pressure gas, this minimum flow of high pressure gas would probably be required continuously even at purge-gas-only low pressure flows.

These limitations are not of great concern in the continuous flaring of solution gas associated with oil production, where the gas may be separated from the oil at different pressure levels. This gas is conserved in Canada wherever it is economic to do so, however, the Coanda high pressure gas assisted flare has found application in the Middle East.

Since the high pressure gas orifice extends completely around the periphery of the flare tip, the orifice slot is very narrow; hence, special precautions must be taken to prevent it from plugging, which could cause a portion of the shell of the "tulip" to overheat.

4.3.5 Low Pressure Air Assisted Flares

In this type of flare the gases being flared and low pressure air flow coaxially to the flare tip, with the low pressure air in the annulus. They are then mixed as the flared gases are ignited. The good mixing of this primary air with the flared gases provides for smokeless operation. The low pressure air (at several inches of water) comes from an electric motor driven blower (usually an axial blower) mounted at the bottom or side of the flare stack. The low pressure air assisted flare is shown schematically in Figure 4.5.

The gases being flared are discharged at the flare burner tip through specially designed ports or slots at high velocity into

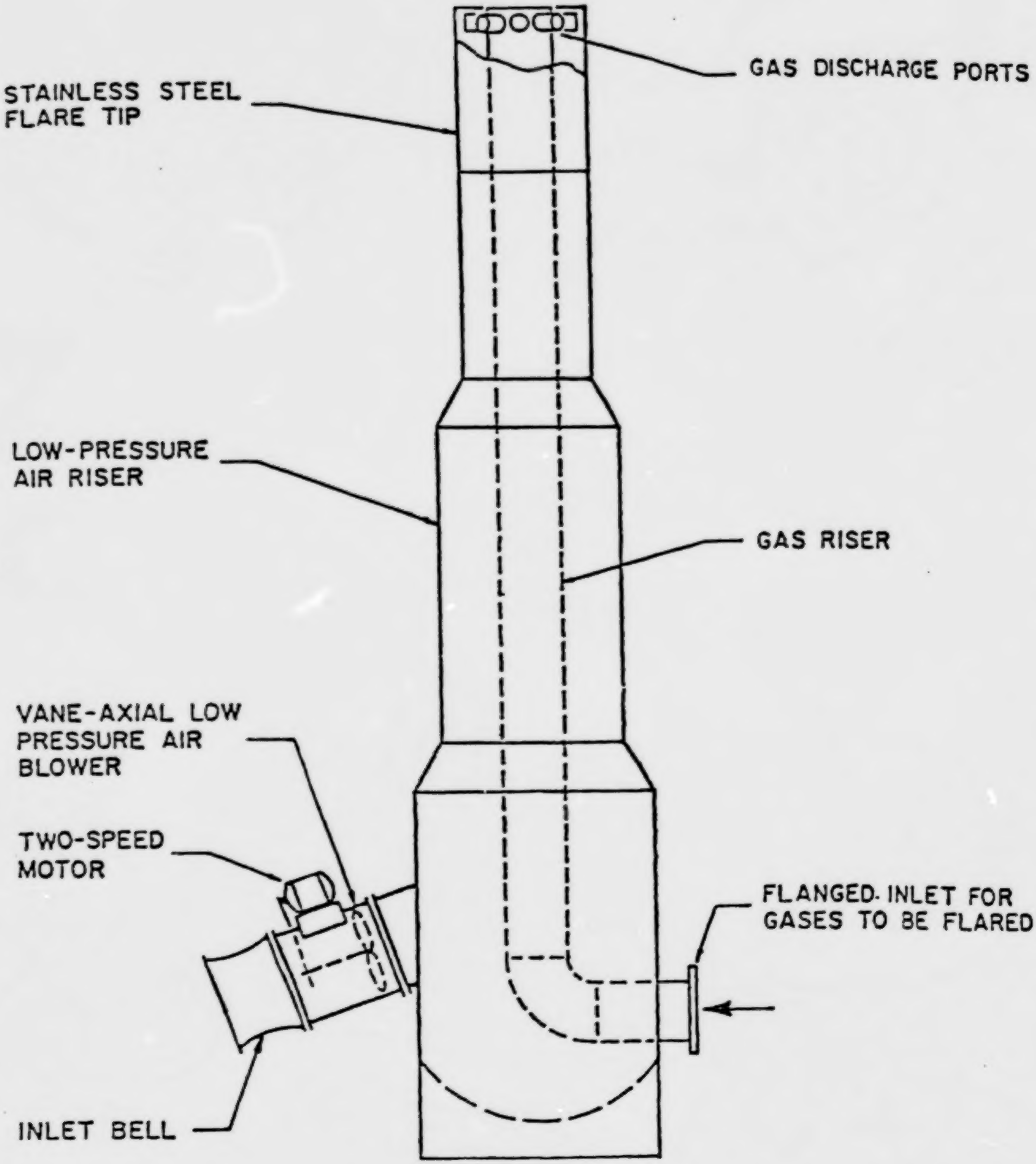

GAS DISCHARGE PORTS
STAINLESS STEEL FLARE TIP
LOW-PRESSURE AIR RISER
GAS RISER
VANE-AXIAL LOW PRESSURE AIR BLOWER
TWO-SPEED MOTOR
FLANGED INLET FOR GASES TO BE FLARED
INLET BELL

Figure 4.5

TYPICAL LOW PRESSURE AIR ASSISTED FLARE

(Source: McGill Incorporated)

the low pressure air that has flowed coaxially up the stack. Due to the high discharge velocity of the gases and the location and angles of the discharge ports, mixing is effectively and efficiently accomplished. Since high discharge velocity is obtained at the expense of pressure drop, the flare is designed to utilize the major portion of the pressure available at the flare stack inlet, as pressure drop across the discharge ports. This minimizes the required size of the tip, and also minimizes the amount of low pressure assist air required, which in turn minimizes the size of the air riser flare support structure. Flare designs with available pressures of 5 to 25 psig (35 to 170 kPag) are typical.

With the air assisted flare the amount of air required for smokeless operation is only a fraction of the stoichiometric air required. For paraffins the fraction is generally 0.3, and for olefins the fraction is generally 0.4.

The discharge velocity of the air at the flare burner tip is typically about 90 feet per second (27 m/s). Consequently, with such a high upward discharge velocity, the ambient wind has less effect on the tilt of the flame during smokeless operation. The excellent mixing between the air and gases being flared also improves the flame quality. The smokeless flame from any air assisted flare burner tip is shorter, straighter and less luminous than the non-smokeless flare flame; consequently, the radiation intensity level at any given point for the same flaring load is significantly lower when using the air assisted system. While this should theoretically permit a shorter flare stack and/or less separation distance (if this is the limiting condition), in most cases the design would be based on the assumption that the maximum emergency flare rate would coincide with a power failure. Further, the flare would probably be designed to operate smokelessly up to a fraction of the maximum flaring rate.

In addition to the specially designed burner tip, pilot(s) and other features of the flaring systems previously discussed will be required, except that no inner refractory lining or windshield is required. The blower is usually provided with a two-speed motor. At low flare gas flow conditions, the low speed will be sufficient to provide smokeless operation with a significant power saving; approximately 10 to 15 percent of the connected load is used at low speed.

4.3.6 Staged Multi-point Flares

The smokeless flaring systems discussed in the preceding sections of this report have been based on the principle of promoting mixing by using steam, water, high pressure gas or low pressure air to assist in introducing air into the flared gases. A more recent development is based on the principle of promoting mixing and eliminating smoke by injecting small sized, high velocity jets of flared gases into the combustion air. The high velocities and turbulence are provided by specially designed small flare tips utilizing the pressure drop available in the flared gases. This results in a system that is capable of smokeless operation at maximum flaring capacity without the use of a utility such as steam, gas or electric power. In appearance, an elevated multi-point flare typically resembles a giant candelabra.

The minimum pressure drop required across the flare tip is approximately 5 psig (34 kPag), however pressure drops over 10 psig (69 kPag) are preferable. A separate, low pressure flare is required for lower pressure streams. However, in many cases these will be relatively lower volume streams, which may not have smoking tendencies.

The use of a large number of small flare tips (attached to pipe sizes one to four inch, 25 to 100 mm) breaks up the large cylindrical flow into smaller portions which promotes the mixing of atmospheric combustion air with the flared gas. Thus this flare system is capable of smokeless operation at maximum capacity. This is also theoretically possible with other smokeless flaring systems, however the large quantities of steam, gas or forced air assist that would be required, at maximum emergency flaring rates of an intermittent flare, rule this out as a practical consideration.

In order to maintain the high velocities and pressure drop levels across the flare tips (necessary for smokeless operation) over the full range of flaring rates, the multi-point flare is usually staged. Staging proportions the number of flare tips in service to the flare gas flow rate. The number of stages can vary from two to five or more. The capacity of the first stage is typically a small fraction of the total capacity. The capacity of each subsequent stage is greater than that of the preceding stage, such as to double or triple the total flaring capacity as each successive stage comes on stream. Flow switches are used to open successive stages as their set points are reached. Snap acting valves are used, which are either fully open or fully closed. To protect against overpressuring the flare header system, a pressure switch is included to override the flow switches and open selected stages if a sudden high pressure in the header is experienced. Rupture disc bypasses are also used to ensure safety in the event of control system malfunction.

A schematic of a typical staging system is shown in Figure 4.6. This particular schematic is for a flare system that would be smokeless on stages one through four, with a fifth stage utility flare tip to handle maximum emergency relief.

Different designs of proprietary flare burner tips are used by different manufacturers and for different gases and different pressure levels. A critical part of the design is the flare tip burner for the first stage. Succeeding stages are set to operate from some appropriate minimum pressure, but the first stage must go from the purge gas flow rate to its full design rate.

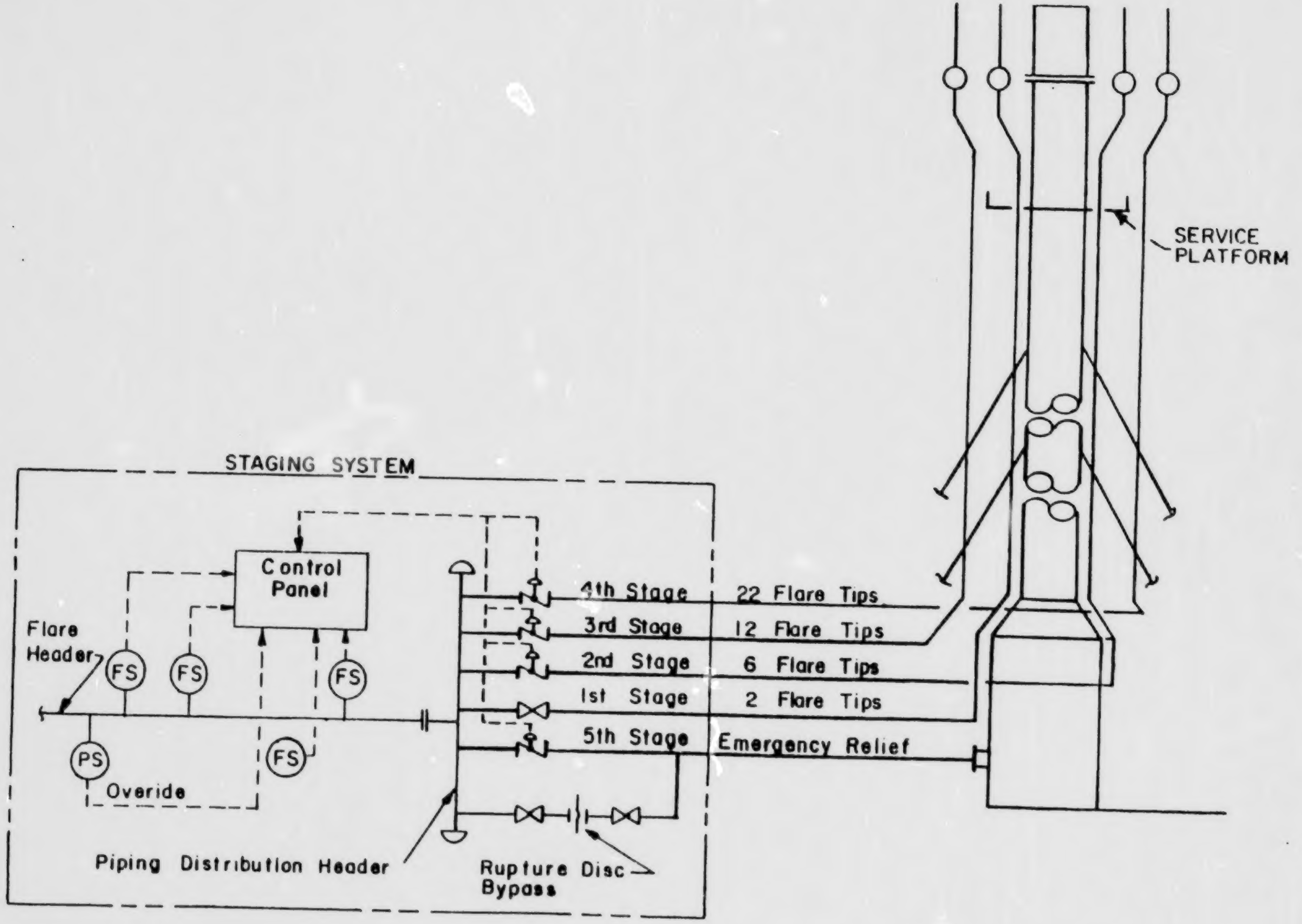

SERVICE PLATFORM
STAGING SYSTEM
Control Panel
Flare Header
FS
FS
FS
FS
FS
PS
Overide
Piping Distribution Header
Rupture Disc Bypass
4th Stage
3rd Stage
2nd Stage
1st Stage
5th Stage
22 Flare Tips
12 Flare Tips
6 Flare Tips
2 Flare Tips
Emergency Relief

Figure 4.6

TYPICAL STAGED FLARE SYSTEM

(Source: McGill Incorporated)

With a staged system only the first stage is open at all times. Succeeding stages are opened only when the flow rate is high enough to ensure a sufficiently high velocity at the flare tip. This velocity in stages two plus will be far greater than the purge level required to keep atmospheric air from entering the flare stack. Hence in a staged flare, consisting exclusively of multi-point tips, it is only necessary to purge the first stage. Since the first stage usually consists of only a couple of flare burners, it requires only a small amount of purge gas. Each of the burners in the first stage has its own pilot. The second and subsequent stages are ignited by the preceding stage.

The good mixing of air and flare gases that results in smokeless operation without external assist also results in lower emissivity. Hence, the radiation from a staged multi-point flare system is lower than the radiation from other types of flare systems. Since this situation does not rely on the maintenance of electric power supply, as with the air assisted flare, this permits shorter overall heights of elevated flares or the use of shorter boom lengths on offshore flares, where radiation is the limiting condition.

For low pressure flares [less than 5 psig (34 kPag) available pressure drop] steam assisted or high pressure gas assisted staged multi-point flares can be used to provide smokeless operation. Steam or high pressure gas consumption is significantly less, as little as 50% of that required for single point flares, and radiation levels are comparable to those of the non-assisted multi-point flares.

4.4 Ground Flares:

The term "ground flare" generally refers to flares where the flare burner(s) are at or near ground level. Ground flares can be generally grouped into two categories, open and enclosed. A more detailed description of these is as follows:

4.4.1 Open Ground Flares

The most rudimentary form of the open ground flare is the pit flare. Pit flares are generally inexpensive flare systems located at a safe distance from other plant facilities where hydrocarbon gases and/or liquids can safely be burned. There is often no concern for smoke prevention. Any of the previously described flare tips used with elevated flares, except the multi-point, can be installed in a horizontal position as a pit flare, however by far the most common is the non-smokeless utility type. The smokeless low pressure air assisted flare is sometimes used, although it is not designed to handle liquids. The flare tip is installed horizontally in the earthen berm surrounding the pit, with the outlet end of the flare tip flush with the inside edge of the berm to protect it from flame impingement. In addition, the bottom of the flare pit is sloped away from the flare tip to keep burning liquids away from it.

Another relatively inexpensive type of open ground flare that is used in uninhabited, desert-type locations, such as the Arctic or the Middle East, is the candle or "mini-flare". This essentially consists of a non-smokeless utility type flare tip that is mounted vertically at grade without any stack. It is installed on a convex mound of sand or earth, topped by a layer of gravel (or other heat resistant insulating material), which buries and protects from thermal radiation the piping leading to the flare, and the permafrost in the case of Arctic installations.

A third type of open ground flare which is smokeless, and much more sophisticated, is the staged multi-point flare. The basic design and method of operation is the same as has previously been described for the elevated staged multi-point flare. In the ground flare case, however, the multiplicity of flare tips are installed vertically at ground level, typically in a rectangular grid pattern, over a wide area to allow adequate air to each burner. The carbon steel distribution piping to the flare tips is buried beneath a layer of earth topped with a layer of gravel, and the perimeter is usually surrounded by an earthen berm to reduce ground level radiation and visual impact. This arrangement is shown schematically in Figure 4.7.

Since the size of such an installation is essentially limited only by the space available, very large smokeless capacities are possible. Currently, such flare systems are installed with smokeless capacities as high as two million pounds per hour (900 t/h).

The cost of the staged multi-point open ground flare is significantly less than the equivalent elevated system of the same capacity. However, the land area required will generally be greater, and the separation distance from other facilities may be greater to account for the possible accumulation of flammable vapors at ground level, should the flare become unignited. In addition the hot gas plume from the installation must be kept away from tall structures.

In general, due to safety and environmental considerations, none of the open ground flares described above would be suitable to flare sour gases, or gases containing other toxic constituents.

Some trade names for the staged multi-point open ground flare are Linear Relief Gas Oxidizer (LRGO) and NAO Iso-Fluidic Oxidizer (NIFO).

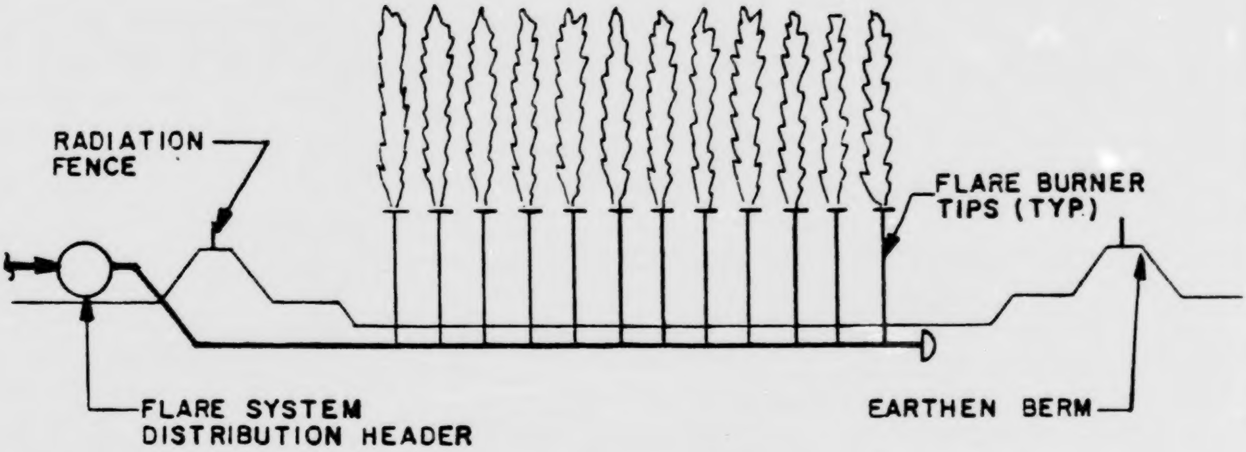

RADIATION FENCE
FLARE BURNER TIPS (TYP.)
FLARE SYSTEM DISTRIBUTION HEADER
EARTHEN BERM

Figure 4.7

TYPICAL OPEN MULTI-POINT GROUND FLARE

(Source: McGill Incorporated)

4.4.2 Enclosed Ground Flares

This type of ground flare system is one in which the flame is completely enclosed within a refractory-lined, vertical carbon steel shell so that there is no thermal radiation and no visible sign of flaring. The shape of the shell structure may be round, square, rectangular or multi-sided such as hexagonal or octagonal, etc. A reasonable maximum capacity for a single ground flare of this type (except for rectangular) is in the order of 100,000 to 200,000 pounds per hour (45 to 90 t/h) as limited by the distance from the shell to the center burners. For higher capacities, multiple units would be necessary, or a rectangular unit which can be a long relatively narrow structure.

The flare burners are typically installed in the staged multi-point arrangement previously described. Steam assist can be used if the pressure drop available in the flared gases is insufficient to otherwise provide smokeless operation. A fence surrounds the combustion chamber to break the wind and reduce noise. This is shown schematically in Figure 4.8. The elimination of thermal radiation allows the enclosed ground flare to be installed in closer proximity to other plant facilities, where this is the guiding consideration.

For invisible, smokeless flaring to a fraction (say 25%) of maximum emergency relief capacity, the enclosed ground flare can be staged in conjunction with a liquid seal and elevated utility flare as shown in Figure 4.9. Another hybrid arrangement that is available includes a relatively tall enclosure, with multi-point burners mounted on the top around the periphery. This provides for 100% smokeless capacity, with a portion of capacity both invisible and smokeless.

With a relatively tall enclosure the enclosed ground flare can flare gases containing some hydrogen sulfide and meet maximum ground level limitations for sulfur dioxide concentrations. The safety aspects of this application should the flare become unignited would, however, require close scrutiny.

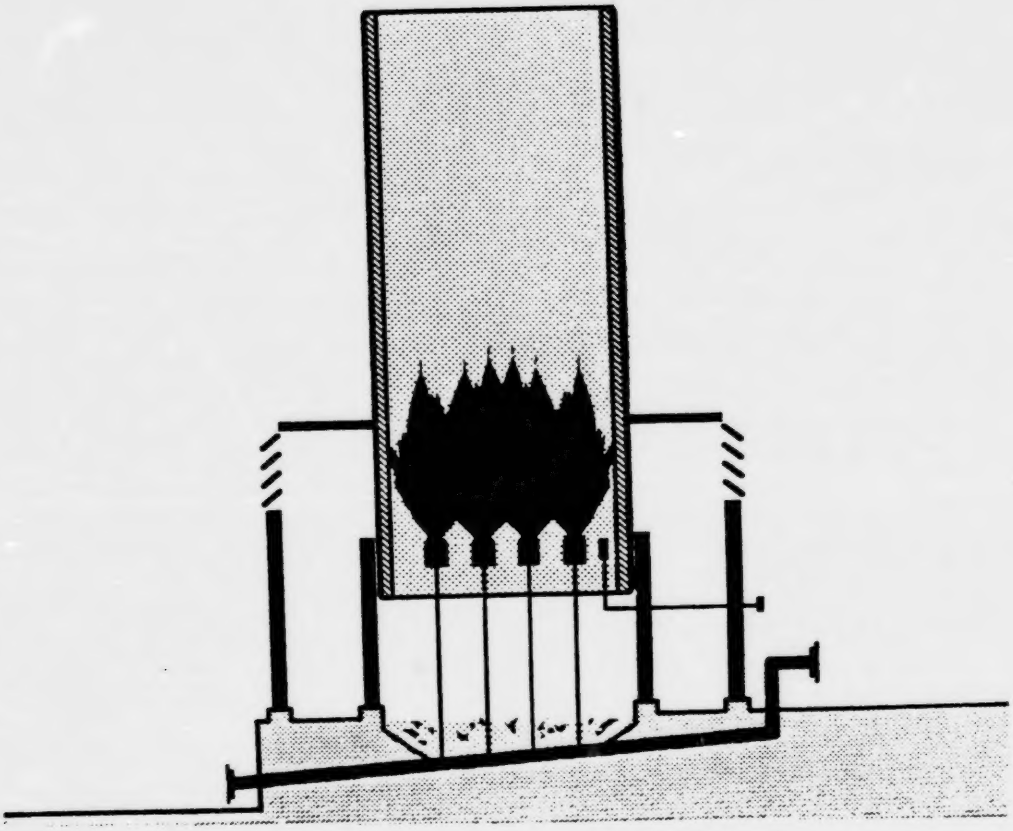


Figure 4.8

TYPICAL ENCLOSED GROUND FLARE

(Source: NAO, Inc.)

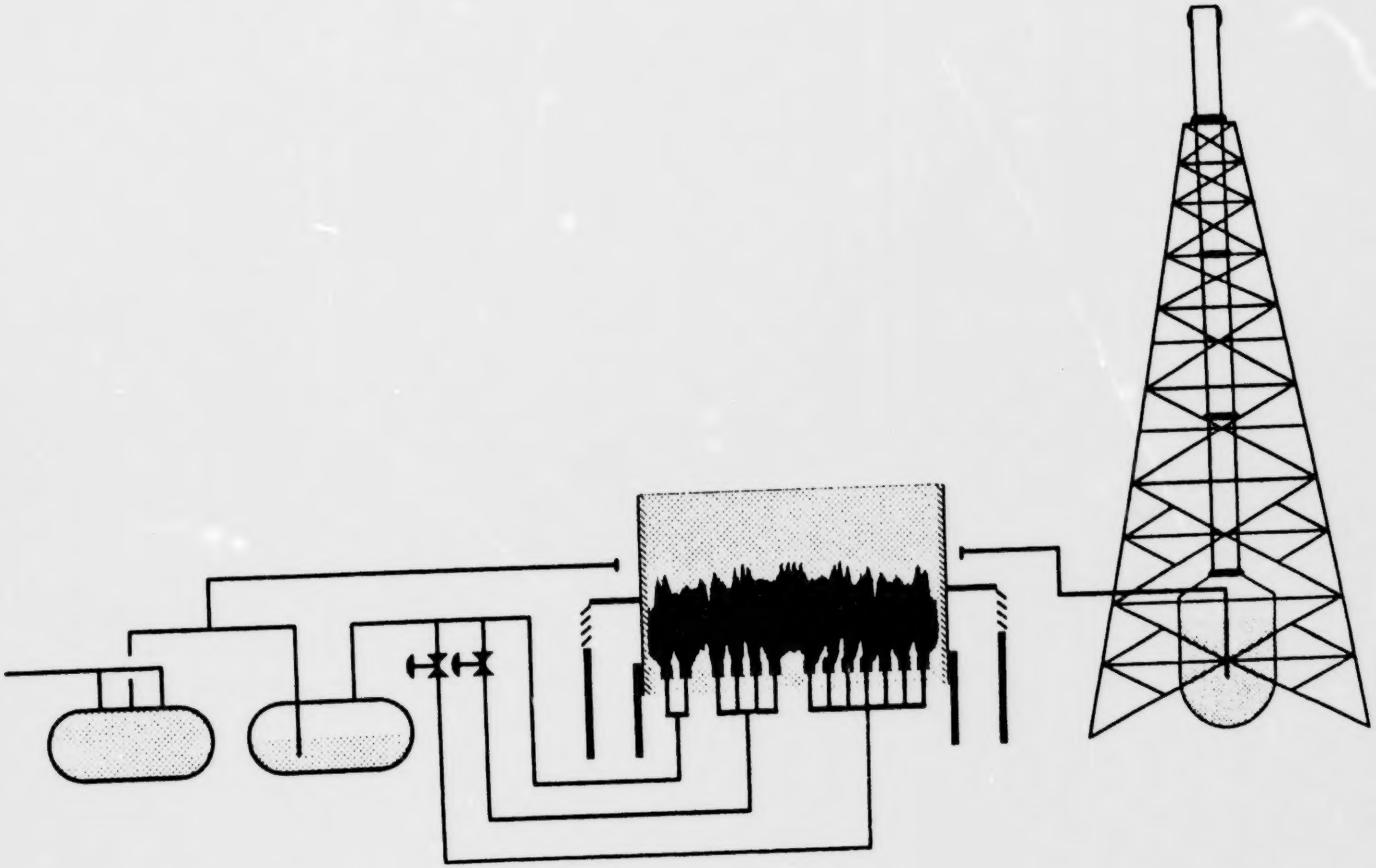


Figure 4.9

COMBINATION ENCLOSED GROUND FLARE AND ELEVATED FLARE

(Source: NAO, Inc.)

Some trade names for the staged multi-point enclosed ground flare are NAO Populated Area Combustor (NPAC) and Zink Thermal Oxidizer Flare (ZTOF).

A very close relative of the enclosed ground flare is the waste gas incinerator that is shown schematically in Figure 4.10. These are in use primarily in the disposal of relatively small quantities of solution gas. They may be skid-mounted essentially at ground level, or mounted on a stack in the case of higher hydrogen sulfide concentrations.

4.5 Offshore Flares:

Due to the high cost involved in locating the flare tip a sufficient distance from offshore platform or production ship facilities, the prime concern is minimizing thermal radiation, and to a lesser degree, providing smokeless operation. Few offshore facilities flare sufficient quantities of sour gas to make this a major concern. There are several types of flare systems used with offshore facilities, including:

- A flare stack mounted vertically on the platform, with a knockout drum in the base to prevent liquid carryover, and with the overall height of the flare based on radiation considerations.

- A flare boom mounted at an angle off the platform such that if there is any liquid carryover, it will not fall back onto the platform. Again, the length of the boom will be determined by radiation considerations.

- A flare mounted on a separate flare support or platform. The final length of header and the flare tip can either be vertical or angled. The header can either be supported above the water on a bridge support, or can be an underwater header. One problem with the underwater header system is that condensate can build up. Periodically,

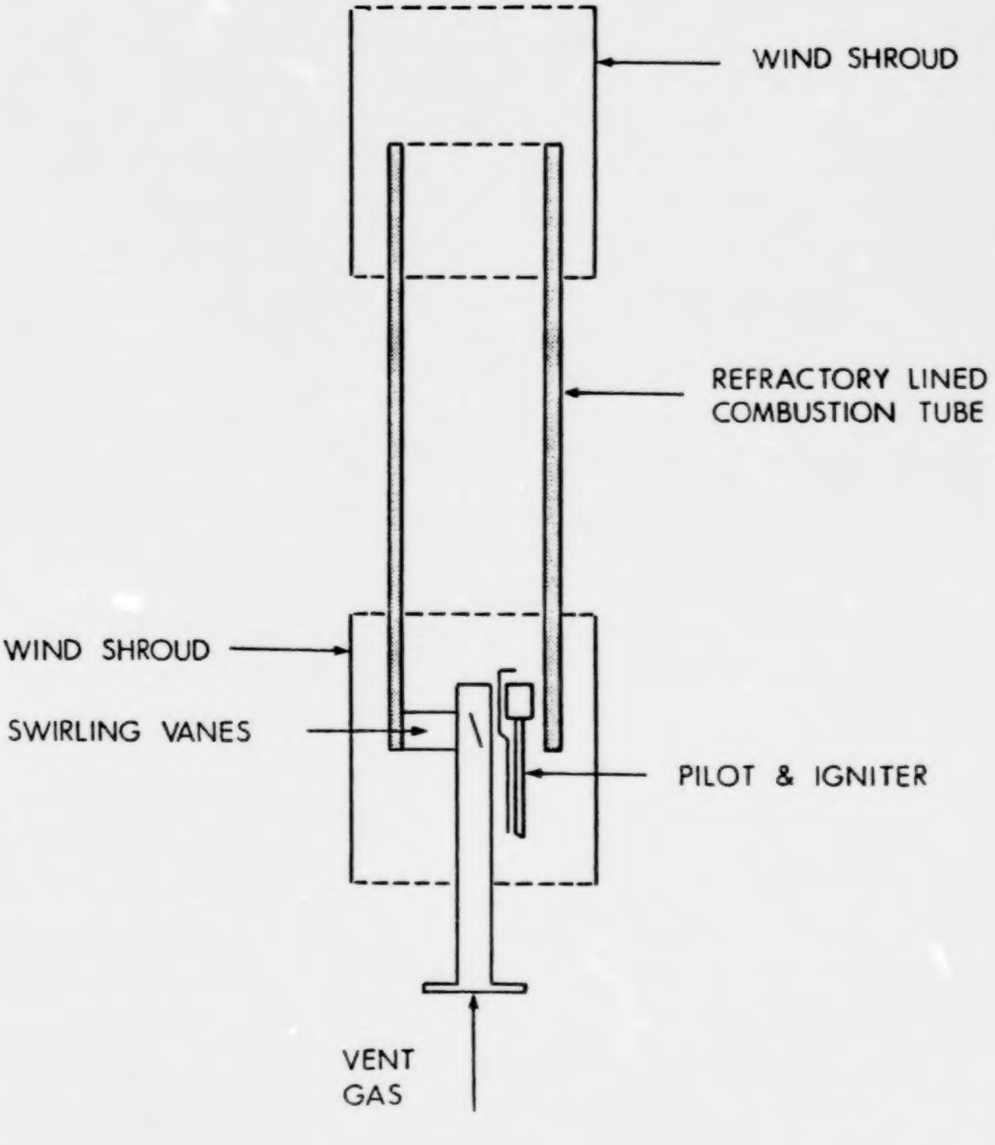

WIND SHROUD
REFRACTORY LINED COMBUSTION TUBE
WIND SHROUD
SWIRLING VANES
PILOT & IGNITER
VENT GAS

Figure 4.10

WASTE GAS INCINERATOR

(Source: Western Research)

this condensate has to be forced out of the header by allowing a large flow of gas to the flare. Another concern is the reliability of ignition systems with underwater headers.

- An enclosed ground flare mounted on a production ship, where generally more deck space is available.

It is common to have separate high and low pressure flare headers on offshore platforms. Single point utility flare tips can be used, usually placed as close together as possible to minimize flame impingement. Staged multi-point flares or air assisted flares, or a combination of both for high and low pressure, significantly reduce thermal radiation and hence significantly reduce the boom lengths or distances required between the flare and the platform.

4.6 Flare Seal Systems:

Flare seal systems fall into two general categories: purge reduction seals and liquid seals. These are described in the following subsections.

4.6.1 Purge Reduction Seals

The large internal volume of the larger diameter single point flare tips, stacks and connected flare header piping presents a hazard if atmospheric air is permitted to enter the flare stack through the flare tip and mix with the low flow rate purge gas, causing a potentially explosive air-gas mixture. The approach to solving this safety hazard is to supply a sufficient continuous minimum purge flow of oxygen-free gas to the flare system that will keep atmospheric air swept out. Minimum recommended purge gas velocities for larger diameter flare tips are as follows:

Minimum Recommended Purge Gas Velocity [FPS, (m/sec)]

Purge Gas	Flare Tip Size [Inches, (mm)]			
	24 (610)	36 (910)	48 (1220)	60 (1520)
Methane	.043 (.013)	.078 (.024)	.119 (.036)	.165 (.050)
Nitrogen	.032 (.010)	.057 (.017)	.087 (.026)	.121 (.037)
Propane	.016 (.005)	.029 (.009)	.045 (.014)	.062 (.019)

This table illustrates that a more buoyant purge gas (methane) requires a greater purge gas velocity than nitrogen to insure a safe stack. Also, since the heavier-than-air gases (such as propane) are displaced in a piston-like fashion, a much lower purge gas rate is effective.

Purge gas is normally added at the upstream end(s) of the flare header(s) so that it can purge the entire system through to the flare tip. There are some exceptions to this. One exception is a staged system where the final stage is a large single point flare. In this case purge gas would be injected just downstream of the staging device (valve or liquid seal), in addition to the purge gas added to the upstream end of the flare header. Another exception is the case where there is a vapor recovery system (see below) upstream of the flare, in which case purge gas would be added just downstream of the liquid seal.

Purge reduction seals reduce the amount of purge gas that is required to provide a safe stack. As illustrated by the above table, these seals provide the maximum benefit in terms of purge gas reduction in the larger diameter single point flares. They are not used with staged flares, consisting exclusively of multi-point tips, since only a few small diameter tips are purged, and they are seldom used with air assisted flares. Purge reduction seals are of two basic designs as described below, the velocity seal and the density seal.

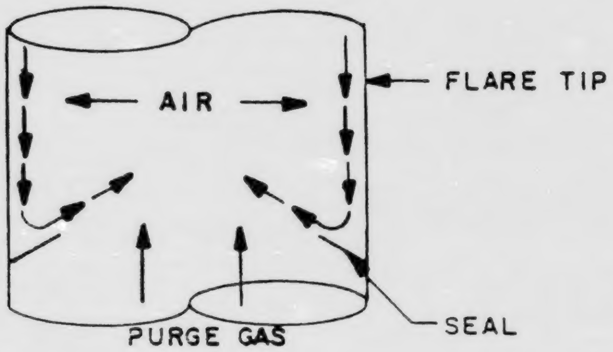

AIR
FLARE TIP
SEAL
PURGE GAS

Figure 4.11

TYPICAL VELOCITY SEAL

(Source: McGill Incorporated)

4.6.1.1 Velocity Seals

This type of seal is shown schematically in Figure 4.11. It is also known by the trade names Fluidic Seal and Arrestor. Atmospheric air enters through the flare tip and hugs the inner wall of the cylinder. When the air encounters the velocity seal it is forced to turn back up and is then swept out by the flow of purge gas. The velocity seal is commonly installed with multiple baffles. It is effective with purge gas velocities as low as 0.03 ft. per second (0.009 m/s) of methane, for any of the flare tip sizes shown in the foregoing table.

The velocity seal is much smaller than a density (or molecular) seal for the same service and is usually fabricated as an integral part of the flare tip, and can be installed right at the outlet end of the tip. Since the velocity seal is smaller than the density seal, it is less expensive, and in addition the structural load on the flare stack is much less so the stack is less expensive. However, the volume of purge gas that the velocity seal requires to keep the stack free of atmospheric air is greater than the density seal requires, and in addition, upon interruption or loss of purge gas flow, the effectiveness of the velocity seal is lost immediately.

Velocity seals can also be installed horizontally for pit flare applications provided there are no liquids in the flared gases.

4.6.1.2 Density Seals

The density seal, also known as the molecular seal, is shown schematically in Figure 4.12. The purge gas is forced to make two 180° bends as it flows through the seal. The air thus encounters a trap caused by the difference in molecular weight between air and the purge gas. If the purge gas is lighter than air, the trap forms in the upper portion of the inverted cylinder. If the purge gas is heavier than air, the trap is

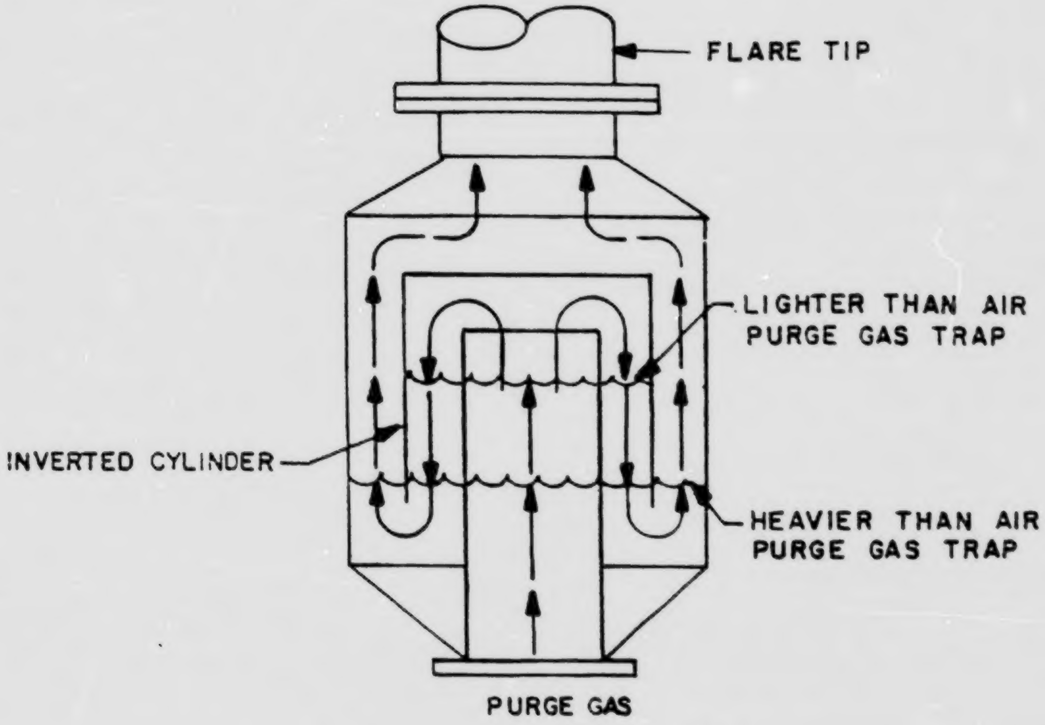

FLARE TIP
LIGHTER THAN AIR PURGE GAS TRAP
INVERTED CYLINDER
HEAVIER THAN AIR PURGE GAS TRAP
PURGE GAS

Figure 4.12

TYPICAL DENSITY SEAL

(Source: McGill Incorporated)

formed in the lower portion of the outer cylinder. This seal is effective even when nitrogen is used as a purge gas. The molecular type seal requires a purge gas rate of only 0.01 ft. per second (0.003 m/s) of methane to be effective.

Because of the flow reversals the density seal is typically larger in diameter than the flare riser in order to prevent flow restrictions. Due to the volume of the contained gases within the seal, the density seal is able to provide continued protection for some period of time even upon interruption or loss of purge gas flow. The length of time that the seal remains effective depends upon the weather conditions.

The density seal is typically located just below the flare tip. Most of the seals are installed vertically, but there are horizontal density-type seals available for pit flares and other applications.

A disadvantage which results from the very low purge gas rates which are possible with the density seal is the problem of "burn-back". Burn-back refers to the flame moving down inside the flare tip at very low exit velocities. This will cause rapid deterioration of any metal, and hence it necessitates the added cost of internal refractory lining to mitigate the effects of flame impingement, or a specially designed flare tip to prevent or minimize burn-back. One such design discharges the flare gas through a relatively small annular slot instead of the traditional large diameter round opening. To provide adequate flow area the overall diameter of the flare tip has to be increased. There are thus three elements of additional capital cost (seal cost, structural cost and flare tip cost) for the density seal as opposed to the velocity seal. For many installations, and in particular gas processing plants, this additional capital cost would probably not be justified by the saving in purge gas costs.

4.6.2 Liquid Seals

A liquid seal is a vessel containing a level of liquid (normally water) through which the flare gases must bubble in order to reach the flare. It provides a physical barrier to flame and keeps the flare header pressurized to a level dependent on the depth of the water. Internal baffles are provided to prevent a pulsating flow of gases to the flare. A typical liquid seal is shown in Figure 4.13. Water make-up and drain, a heating coil to keep the water from freezing and insulation are normally provided.

A liquid seal used in an elevated flare system is normally made the lower or base section of the stack. Often there will be a specially designed knockout drum and liquid seal combination, with the knockout drum on the bottom and the liquid seal directly above it. For use in other systems or applications, the liquid seal can be a separate individual vessel.

Liquid seals are used for several reasons, including:

- To insure that the flare header has a positive pressure so that if there is a leak or an opening, the flare gas will leak out instead of outside air being drawn into the header.
- To provide positive protection against flame flashback. For some gases, such as acetylene, ethylene oxide, and hydrogen a liquid seal is the only sure way to prevent flashback. A normal grid-type flame arrestor will not stop a flashback of those gases. The design of the liquid seal internals is extremely important in this application because the gas must bubble through the liquid in discrete bubbles in order for the liquid to stop any flashback.
- To prevent flare gases from going one direction (until the gas pressure reaches the seal depth) and to direct the gas in a second direction. This method would be used in a ground flare-elevated flare system and in a vapor recovery system.

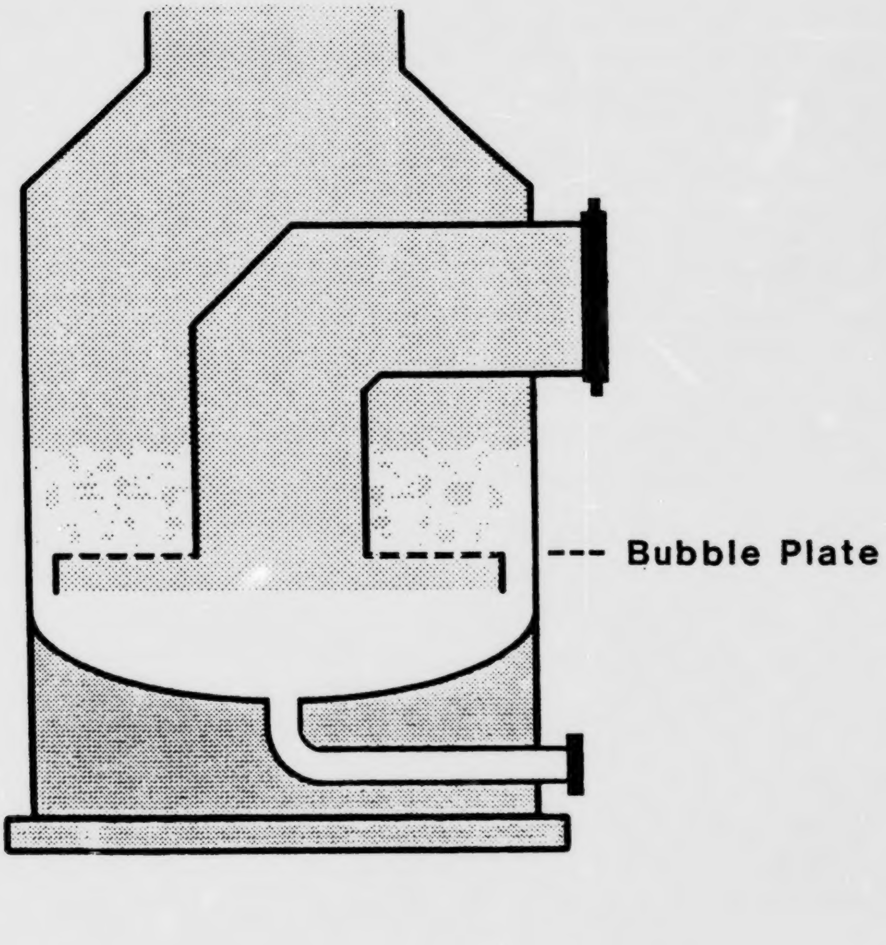

Bubble Plate

Figure 4.13

TYPICAL LIQUID SEAL

(Source: NAO, Inc.)

In the ground flare-elevated flare system, a liquid seal would be used to direct the flare gases to the ground flare until the capacity of the ground flare was reached. At such time, the backpressure at the liquid seal would equal the seal depth and gas could begin to flow through the liquid seal to the elevated flare as well as continuing to flow to the ground flare.

In the vapour recovery system, the liquid seal would be used to direct the flare gases to a compressor until the capacity of the compressor was reached. At such time the backpressure at the liquid seal would equal the seal depth and gas would begin to flow through the liquid seal to the elevated flare as well as continuing to flow to the compressor.

Since the liquid seal can be installed no closer to the flare tip than the base of the stack, it does not serve as a purge reduction seal. If reduction in purge gas consumption is desired, a velocity or density seal must also be installed.

A liquid seal can only be maintained under low gas flow rates. With normal to high flare gas rates, the water in the seal will be swept out with the gas and the level control system will not be able to maintain the necessary liquid level. This does not endanger the safety of the system, however, because at such gas rates the velocity in the header will be much greater than the flame flashback velocity.

4.7 Flare Control Systems:

4.7.1 Control for Smokeless Operation

Control of multi-point flares for smokeless operation is done by staging, the methods for which have previously been discussed. Some of the methods that are used to control the injection of a smoke suppressant (such as steam, water, high pressure gas or air) are the subject of this subsection.

The simplest control method is visual monitoring of the flare by the operators, either directly or by using a TV camera with a screen in the control room. The flow of smoke suppressant is controlled by manual adjustment of the control valve, or in the case of air assist, by starting the blower or increasing its speed. This has the disadvantage of being a feedback control method; some smoking will occur before corrective action is taken, and perhaps an excessive amount depending upon the watchfulness of the operators. In addition it is prone to excessive injection of smoke suppressant, particularly at lower flaring rates or after a high flaring rate has been reduced. This is wasteful, can cause excessive noise, and in the case of steam (or water) injection, excessive suppressant flows can result in reduced combustion efficiency.

Some automatic control systems for smokeless operation are as follows:

- Monitoring of the flame using thermocouple sensors surrounding the flare tip. These sensors measure radiation and automatically adjust the amount of smoke suppressant accordingly. This system's major disadvantage is that the sensors are exposed to the flame and maintenance, replacement, or adjustment cannot be made during operation. This type of control is also a feedback system.
- Monitoring of the flame using a remotely located optical sensor to measure radiation and control the smoke suppressant. The sensor is located at grade, and is external to the flare system; therefore, maintenance and adjustment can be performed during flare operation. The disadvantages of this system include a problem of selecting the proper location in order to minimize the interference by the sun, and it may sometimes be difficult to position the sensor(s) to accommodate both low and high flaring rates. It is also a feedback system.
- Measurement of the flow in the flare gas header, and adjustment of the smoke suppressant flow by ratio control. Hence the

amount of smoke suppressant injected is proportional to the amount of gas being flared, and it is a feed forward system. The smoke suppressant arrives at the flare tip at the same time as the gas being flared. Two disadvantages are the limited range of measurement possible for the flare gas flow, and the inability to compensate for changes in flare gas composition. Commercial flow instruments typically are accurate over flow ranges of approximately 10 to 1. This would not normally be wide enough to cover the range of flows encountered in an intermittent flare (310). Changes in flare gas composition affect the relationship between the actual flow and the primary measurement (such as pressure or pressure drop), and the amount of smoke suppressant required for a given quantity of flared gas.

It will be evident from the above discussion that there is no entirely satisfactory method to control the injection of smoke suppressants.

4.7.2 Purge Gas Control

Purge gas flow rates are normally set at a constant volume at the injection point(s) to provide the required purge gas velocity at the flare tip. However, under circumstances where a relief of high temperature gas (over 200°F, 93°C) can occur during low ambient temperature conditions (or during a rainstorm if the flare header is above ground) additional purge gas control may be required. This is because of the shrinkage that would occur in the flare header after the flow of flared gas ceases and the gas begins to cool. This shrinkage will pull outside air into the flare stack, and into the flare header unless it is equipped with a liquid seal. Purge reduction seals will not prevent this.

To correct this situation, an additional large volume of purge gas is needed for a short period of time. Typically, a control system is used consisting of a temperature switch (to sense the high gas temperature) and a pressure switch (to sense the low header pressure) wired to a control valve in a purge gas supply line. If a high temperature and low pressure exist in the flare header then the control valve is opened, admitting additional purge gas into the header.

4.8 Flare Pilots and Ignition Systems:

The most commonly used method of assuring reliable ignition of the flared gases is the use of continuously burning flare pilot(s). The number of pilots used on a flare is usually a function of the flare tip diameter, typically as follows:

Flare Tip Diameter	Number of Pilots
Up through 8 inches (200 mm)	1
10 inches (250 mm) to 20 inches (500 mm)	2
24 inches (610 mm) and larger	3

A typical flare pilot assembly is shown in Figure 4.14. It consists of the pilot burner, pilot windshield, ignitor pipe, and a monitoring thermocouple. The pilot burner includes an inspirator for primary air. The thermocouple can provide for indication, alarm and/or automatic re-ignition in the event that the pilot goes out. Maintenance of a visible pilot flame at all times would use an excessive amount of pilot fuel gas. In some cases spot checking may be adequate in which case the thermocouple is not required.

The pilot fuel gas can be natural gas, refinery fuel gas, propane, etc. For many years the standard flare pilot fuel gas rate was 350 SCFH (9.9 m^3/h) of natural gas, or the equivalent heating value for other gases. More recent energy conserving designs have lowered this figure to 100 SCFH (2.8 m^3/h), and at least one manufacturer offers a pilot design rated at 45 SCFH (1.3 m^3/h).

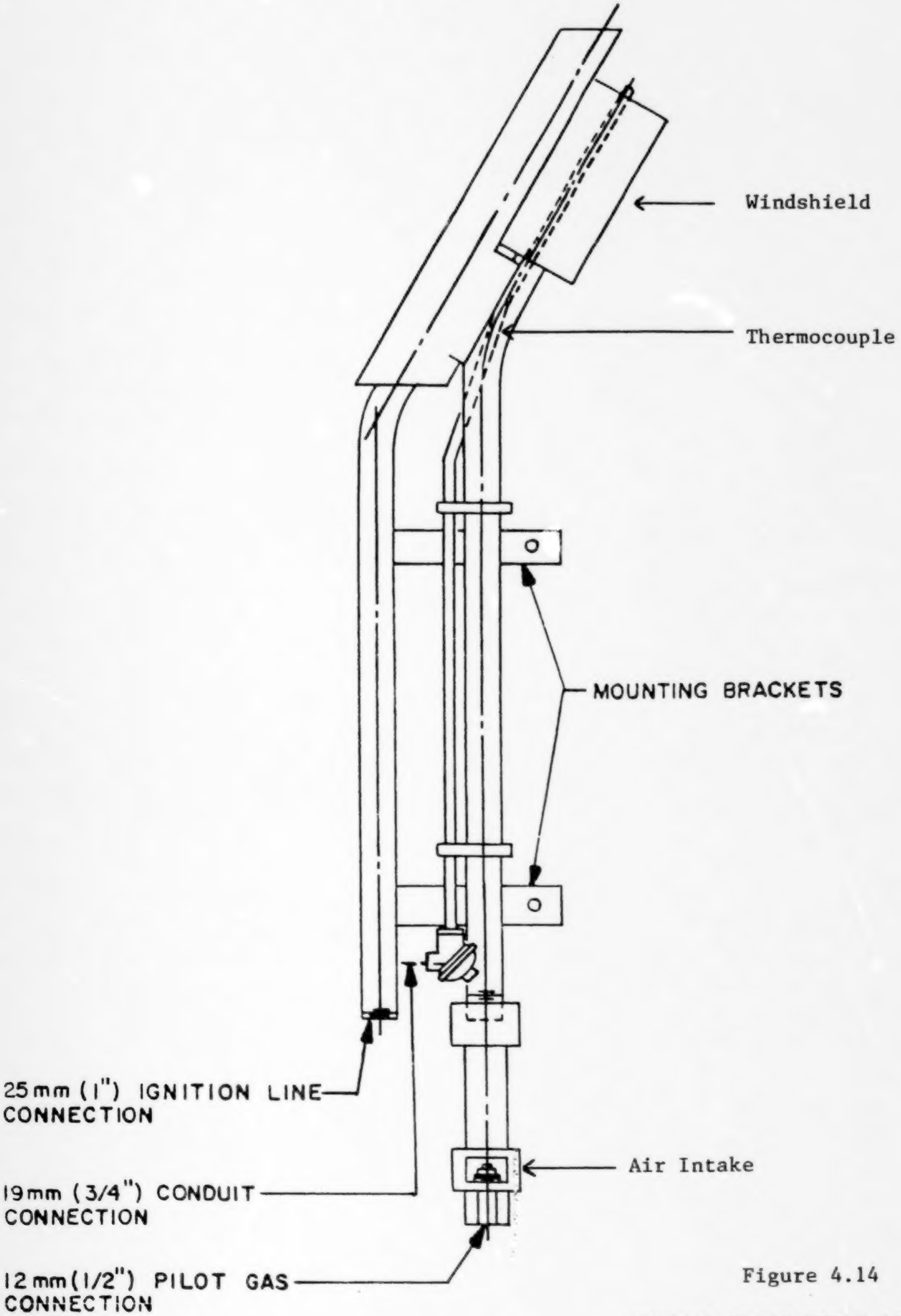

Windshield
Thermocouple
MOUNTING BRACKETS
25mm (1") IGNITION LINE CONNECTION
19mm (3/4") CONDUIT CONNECTION
Air Intake
12mm (1/2") PILOT GAS CONNECTION

Figure 4.14

TYPICAL FLARE PILOT ASSEMBLY

(Source: McGill Incorporated)

There are two types of pilot ignition systems in general use, flame front generator ignition systems and electrical ignition systems.

4.8.1 Flame Front Generator Ignition Systems

In the most commonly used version of this ignition system, compressed air (at 15 to 30 psig, 103 to 207 kPag) and fuel gas (at 15 psig, 103 kPag) are mixed in flammable proportions at the flame front generator (or ignition) panel, and this mixture travels through the ignition piping to the flare pilot. The mixture is then spark-ignited at the panel using an electrical supply (at 110, 220 or 440V) to generate a ball of fire or "flame front", which travels through the ignition piping to the pilot.

The ignition panel consists of compressed air and fuel gas connections, power connection, valves and gauges, a mixing chamber, combustion chamber and spark plug. These components can be enclosed in a weatherproof and/or explosion-proof housing. Since the panel is only used when the flare pilots need to be ignited, the utility demand is small. Ignition panels can be designed for manual and/or automatic operation, if a monitoring thermocouple is included in the flare pilot assembly. If there is no thermocouple, or if it is inoperative, a spot check can be made by admitting pure fuel gas to the ignition piping, followed by a slug of air.

The location of the ignition panel is extremely flexible since it can light the pilot with the ignition system being as far as one mile of equivalent distance away; however, for distances greater than 2,000 feet (610 m), special design considerations need to be included such as using rotameters on the compressed air and fuel gas. The ignition panel should not be located at the base of the flare stack due to higher radiation levels and the hazard of liquid carryover.

The ignition piping from the ignition panel to the flare pilot is normally one inch (25 mm) carbon steel pipe, with no change in size anywhere along the way. There is typically a separate ignition line for each pilot, although designs are available where a singe line is used for two or three pilots. Since the products of combustion, after the flame front has passed through the ignition line, include water vapor, drain valves must be provided at the low points to remove condensate.

Ignition systems using a piezoelectric crystal to generate the voltage, or battery powered systems, are available if electricity is not available. If compressed air is not available, compact blower systems can be supplied which are limited to flame front travel of less than 1800 equivalent feet (550 m). Venturi inspirating type ignitor systems are also used where compressed air in not available. These require larger sized piping and are limited to flame front travel of 300 feet (90 m) of straight pipe. This latter type of ignitor is also used where it is not possible to drain the low point(s) in the ignition line(s), such as sub-sea applications.

A special type of flame front ignition system developed by a Canadian manufacturer utilizes the same pipeline to supply the pilot fuel gas and to transmit the flame front. In this case a temporary flame retention nozzle, supplied by a separate fuel gas line, maintains the flame for the time required for the air-fuel mixture to purge the combustion products of the flame front from the line and re-ignite the continuous flame nozzle. The general arrangement of this system is shown in Figure 4.15. The same inspirating venturi provides air for the flame front mixture, and subsequently primary air for the continuous pilot, so that no compressed air is required. However, the maximum pipe length from the venturi to the pilot(s) is limited to 400 feet (120 m).

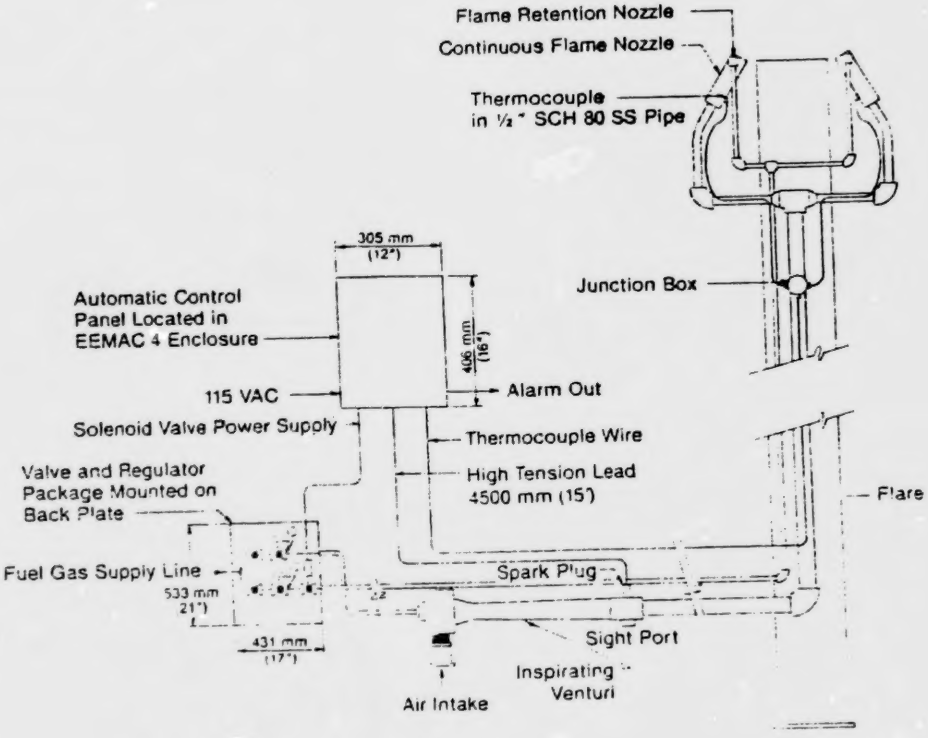

Flame Retention Nozzle
Continuous Flame Nozzle
Thermocouple in ½" SCH 80 SS Pipe
Junction Box
305 mm (12")
Automatic Control Panel Located in EEMAC 4 Enclosure
406 mm (16")
115 VAC
Alarm Out
Solenoid Valve Power Supply
Thermocouple Wire
High Tension Lead 4500 mm (15')
Flare
Valve and Regulator Package Mounted on Back Plate
Fuel Gas Supply Line
533 mm (21")
Spark Plug
431 mm (17")
Sight Port
Inspirating Venturi
Air Intake

Figure 4.15

"WESTECH" FLAME FRONT IGNITION SYSTEM

(Source: Westech Industrial Ltd.)

4.8.2 Electrical Ignition Systems

In electrical ignition systems a spark is generated at the flare tip to ignite the pilot(s), to ignite the flared gases directly or, on larger diameter flare tips, to ignite a slipstream of the flared gases. The advantages are a substantial saving in utility costs if the continuously burning pilot can be eliminated, and a significant reduction in re-ignition time. The spark in an electrical ignition system can be continually pulsating every few seconds. The time required for an automatic flame front generator to re-ignite a pilot after a flameout will be significantly longer, depending on the length of the ignition piping. Further, if it does not re-ignite on the first attempt, some time must elapse before each subsequent attempt. Also the number of automatic attempts at re-ignition must be limited to prevent overheating of the system.

The chief disadvantage of electrical ignition systems has been their lack of reliability. The sparking electrodes are prone to rapid deterioration due to high temperatures, and to fouling by carbon particles, etc. Hence their use has largely been confined to applications involving infrequent flaring and relatively small diameter flare tips, and/or where no pilot gas is available.

A recently developed design by a Canadian manufacturer is claimed to have solved these problems. This is illustrated in Figure 4.16. The sparking electrodes are venturi probes of a hollow wedge-shape design which allows air to be drawn through them. When placed in a gas stream, the wedge-shaped tips create a low pressure area at the mouth of the hollow probes, which inspirates atmospheric air into the gas stream. This cools the probes, and prevents any carbon particles from settling on the tips of the probes. It also provides a flammable air/gas mixture at the location of the spark.

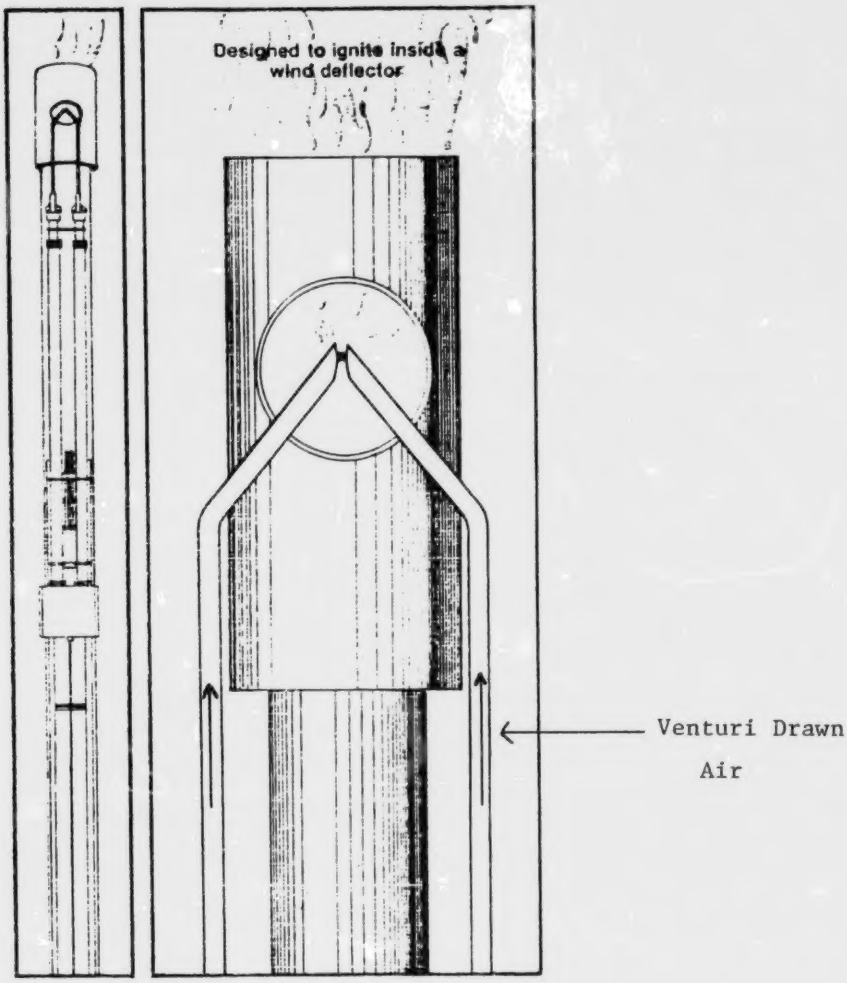

Designed to ignite inside a wind deflector
Venturi Drawn Air

Figure 4.16

"MACTRONIC" ELECTRICAL IGNITION SYSTEM

(Source: Mactronic Systems Ltd.)

4.9 Miscellaneous Items:

4.9.1 Knockout Drums

The knockout drum is a very important component in any flare system. Its function is to adequately remove liquid from the flared gases. Failure to provide a properly designed knockout drum can result in "burning rain" caused by large droplets of flammable liquid being entrained up the flare stack, and/or descending "sheets of fire" as slugs of liquid emerge from the flare tip. In strong winds these can travel long distances from the flare stack before reaching the ground or adjacent structures, posing a severe hazard to personnel and property.

The sizing of the knockout drum is based on two considerations: Sufficient vapor space is required to reduce the vapor velocity and permit separation of the liquid particles, and sufficient liquid holdup volume must be provided. Since the flare can handle small-sized liquid droplets, it is usual to base the allowable vapor velocity on that necessary to separate droplets from 300 to 600 micrometers in diameter. Liquid holdup volume is generally based on the maximum amount of liquid that would be anticipated to accumulate in 20 to 30 minutes flaring at maximum emergency rates. Both horizontal and vertical vessel designs are used, the choice being often decided by economics. When large liquid storage is required and the vapor flow is high, a horizontal drum is often more economical. For detailed recommendations on the sizing of knockout drums see API Recommended Practice 521 (201).

Horizontal and vertical knockout drums are constructed in many designs, the main differences consisting in how the path of the vapor is directed. The various designs include the following:

1. A horizontal drum with the vapor entering one end of the vessel and exiting at the top of the opposite end (no internal baffling).

4.9.1 Knockout Drums (cont'd)

2. A vertical drum with the vapor inlet nozzle on a diameter of the vessel and the outlet nozzle at the top of the vessel's vertical axis. The inlet stream should be baffled to direct the flow downward.

3. A vertical vessel with a tangential inlet nozzle.

4. A horizontal drum with the vapor entering at each end on the horizontal axis and a center outlet.

5. A horizontal drum with the vapor entering in the center and exiting at each end on the horizontal axis.

6. A combination of a vertical drum in the base of the flare stack and a horizontal drum upstream to remove the bulk of the liquid entrained in the vapor.

It is common to include a vertical knockout drum at the base or lower section of the flare stack. Often there will be a specially designed knockout drum and liquid seal combination, with the knockout drum on the bottom and the liquid seal directly above it.

It should be noted that, at low flare gas flow rates, even a well-designed knockout drum will not prevent the accumulation of some immiscible liquids (usually hydrocarbons) above the water in a downstream liquid seal (unless it is a flow diversion seal).

4.9.2 Flame Arrestors

Flame arrestors are used to stop flame flashback. A standard grid-type flame arrestor can be used for mixtures of most gases with air or oxygen. However, for some gases such as acetylene, ethylene oxide, and hydrogen, this grid-type of flame arrestor is not sufficient. A properly designed liquid seal must be used.

Another disadvantage of the grid-type flame arrestor is that it is subject to plugging due to the many small passages. Hence its application is limited to situations where the flare gases are non-corrosive and are dry and free of any liquid which might congeal, and consequently flame arrestors are not normally used in emergency flare systems.

5.0 CAPITAL COSTS

5.1 General

Estimates have been prepared to indicate the capital costs of various "flare systems"

1) For alternate burning arrangements which may be applied at a typical large sour gas processing plant located in Alberta.
2) For alternate burning arrangements which may be applied at a medium and a small sized version of the typical plant in 1).
3) For a staged multi-point ground flare.

The typical plant and a typical flare system with its alternate burning arrangements has been focussed upon to permit the meaningful comparison of the different arrangements of burning waste gas.

Flare systems can differ considerably from plant to plant and for a particular plant depending upon the waste gas characteristics and the designer of the system. The actual costs for a particular system may differ somewhat from the costs of the typical system adopted herein but the relative costs of the alternative burning arrangements should remain similar.

The alternates for different sizes of plants are presented to permit economic evaluations as applicable.

The ground flare is presented as a matter of comparison for a plant which may have such an application.

5.2 The Typical Plant

The typical plant chosen for this presentation has the following basic characteristics:

Location - In the vicinity of the City of Red Deer, Alberta
Inlet Gas Capacity - 350 mmscfd (9 859 10^3 M^3/d)
H_2S Quantity - 1.98% by volume

5.2 The Typical Plant (cont'd)

The flaring system is to meet all of the necessary requirements when flaring waste gases as indicated in the following summary.

Stream	1		4		6		10		14	
Component	Inlet Separator Mol %		Regenerator Overhead Mol %		Stabilizer Overhead Mol %		Sales Gas Purge Gas Fuel Gas Mol %		Stream 4 Plus 185% Stream 10	
H_2	--		--		--		--		--	
H_e	--		--		--		--		--	
N_2	3.00		--		tr		3.23		2.1	
CO_2	1.80		46.62		1.24		--		16.35	
H_2S	1.98		51.38		4.31		--		18.03	
C_1	78.54		2.00		6.85		84.25		55.39	
C_2	8.34				11.97		8.49		5.51	
C_3	3.48				24.76		2.84		1.84	
iC_4	0.52				10.73		0.33		0.22	
nC_4	1.25				38.57		0.65		0.42	
iC_5	0.35				1.39		0.11		0.07	
nC_5	0.32				0.10		0.08		0.05	
C_6	0.11						0.01		0.01	
C_7^+ (MW = 100)	0.31						0.01		0.01	
	100.00		100.00		100.00		100.00		100.00	
MW	20.9		38.3		47.4		18.95		25.76	
Flared Quantities										
mmscfd	87	350	3.4	13.5	5	19	As Required for purge & blend		9.6	38.5
10^3 m^3/d	2 450	9 859	95.8	380.3	140.8	353.2			270.4	1 084.5
Duration hrs.	4	1/2	4	1	4	2			4	1
Frequency/annum	12	6	6	6	6	6			6	6
Smokeless Rate										
up to mmscfd	87		-		19					38.5
10^3 m^3/d	2 450				353.2					1 084.5
	25% of plant capacity									

Note: Stream 4 may not be flared without mixing with 185% of Stream 10

i.e. = Stream 14 = 2.85 x Stream 4 Volumetrically

Maximum pressure at Base of Stack 10 psig
69 kPa

5.3 The Inquiry Package

An inquiry package outlining the requirements for a Flare Stack, which would be applicable to the typical plant, was prepared (see Appendix B) and sent to various competent vendors who were asked to present information relative to the Flare Stack, which they would provide to meet the requirements as outlined.

The Flare Stack as outlined was to be incorporated into a flare system which consisted primarily of:

- a Knockout Drum
- Liquid Return Pumps
- One Flare Stack
- Pilot Burner and Ignition System
- all necessary items which would normally be found in such a system and as described elsewhere herein and as presented in:
  Fig. 5.0
  "Schematic Utility Stack Typical Flare System"

Whereas it is not the purpose of this study to design a flare system but rather to obtain information and relative costs for alternate flare burner systems, the flare system as outlined was not optimized.

It should be recognized that other configurations would be acceptable and there may be some operational and economic advantages to some possible rearrangements such as:

- Two Flare Stacks
  - o each at different pressure levels
  - o each servicing particular dedicated streams
  - o each with different burners, perhaps one a utility flare and the other an air assist or similar
- Knockout Drum
  - o may be incorporated with the stack, particularly for smaller sized plants
- Ignition Systems
  - o different ignition systems could be used.

5.3 The Inquiry Package (cont'd)

- Layout
  - o different equipment and piping arrangements could be used.

The information requested from the vendors consisted of budget type cost estimates and pertinent technical information. The diversity of the technical and cost information which was received indicates that identical parameters for design are not used throughout the industry. The cost information was reviewed and adjusted to comparable terms and used as the basis for arriving at Flare Stack costs.

5.4 The Flare System

In this presentation it is considered that an elevated "Flare System" is made up of three major components. Costs were prepared for each.

1) The Flare Stack
2) The Pilot Burner and Ignitor
3) Other Battery Limit Items

It is also considered that these components are situated within a geographic area bounded by Battery Limits.

The estimate which is developed for a particular Flare System is referred to as the Battery Limits Estimate.

Each of the above components provide for elements of the Flare System as generally outlined below. For detail see Table 5.5.

The costs for the Flare Stack Component provide for:

- the transmission of waste gas from ground level to a desired elevation
- the burning of the waste gas through a flare burner and subsequent discharge to atmosphere
- when applicable, the modifications needed for steam assisted burning of the waste gases including transmission of steam from the Battery Limits, but excluding the cost of a steam generator

5.4 The Flare System (cont'd)

- when applicable, the modifications for air assisted burning of the waste gases including the air blower needed for air supply but excluding the cost of an electrical generator or its equivalent
- when applicable, the modifications for other chosen flare burners along with hardware required for operation of the burner.

The costs for the Pilot Burner and Ignitor Component provide for:
In the case of a pilot burner and ignitor

- the transmission of fuel gas to the pilot burner
- the continuous gas burning pilot burner
- the flame front generator ignition system
- the transmission of air to the ignitor

or as an alternate

- an electronic system which may be used in lieu of above or in a combination with the above

The costs for the Other Battery Limit Items Component provide for:

- all other items which are necessary for the flare system and which are situated within the Battery Limits, primarily:
  - Transmission of waste gas from the boundary of the Battery Limits to the Stack via a Knockout Drum
  - Separation of liquids from the waste gas by means of a Knockout Drum
  - Pumping and transmission of separated liquids to the boundary of the Battery Limits
  - Site work, shelters, heating, etc.

5.5 The Alternate Burner Arrangements

The alternate burner arrangements which are presented are distinguished one from the other primarily by the manner in which burning takes place and secondarily by means of the stack seal arrangement which is used, all as described in Part 4.0.

5.5 The Alternate Burner Arrangements (cont'd)

Alternate 1 - Utility Flare (See Fig. 5.0)

Alt 1.0 - No velocity seal
- No density seal

Is considered to be the minimum capital cost installation and has been selected as the Base Case against which the cost of other Flare Systems are compared.

Alt 1.A - A velocity seal only is added to 1.0
Alt 1.B - A density seal only is added to 1.0

Alternate 2 - Smokeless Steam Assist

Differs from Alternate 1 by the modification of the flare burner and by the addition of steam control and steam transmission facilities.

Alt 2.A - Has a velocity seal only
Alt 2.B - Has a density seal only

Alternate 3 - Smokeless Air Assist

Differs from Alternate 1 by the modification of the flare burner and by the addition of air transmission duct work and an air supply blower c/w electric motor.

Alt 3.A - Has a velocity seal only

Alternate 4 - Smokeless Multi-point

Differs from Alternate 1 by the modification of the flare burner

Alt 4.A - Has a velocity seal only

Alternate 5 - Smokeless Staged Multi-point

Differs from Alternate 1 by the modification of the flare burner and by the addition of waste gas stage controls.

Alt 5.A - Has a velocity seal only
Alt 5.B - Has a density seal only

5.5 The Alternate Burner Arrangements (cont'd)

SUMMARY OF ALTERNATES

	ALTERNATE BURNER SYSTEM	O NO SEAL	A VELOCITY SEAL	B DENSITY SEAL
STANDARD				
1	Utility Flare	✓	✓	✓
SMOKELESS				
2	Steam Assist	-	✓	✓
3	Air Assist	-	✓	-
4	Multi-point	-	✓	-
5	Staged Multi-point	-	✓	✓

5.6 Other Cost Options

Other items may be incorporated into the flare system. Costs of the flare system will be affected as will a particular cost component depending upon the nature of the item. Some of the many items which may be considered are as presented below.

5.6.1 Pilot Burner and Ignition System

The costs have primarily been developed based upon pilots burning fuel gas and a flame front propagation ignitor

An electrical only ignitor and flame sustaining system may be desired for Alternates 1 and 2. An electrical ignitor along with a pulsating gas assist pilot may be desired for Alternates 3, 4 and 5. Estimates have been prepared for these alternates and are shown in the following tables as they affect the cost of this particular component.

5.6.2 Liquid Seal

It may be desired to incorporate a liquid seal to provide a back pressure on the flare system. This item would be common to all alternates and would be added to the Other Items component of cost as indicated in the tables.

5.6.3 High Pressure Gas Assist

It may be desired to consider High Pressure Gas Assist as yet another alternate for the burning system.

These costs have not been developed in detail however, an examination of the systems indicate that the hardware is very similar to Alternate 2 Steam Assist and so the capital cost will be much the same.

Similarly when examining the systems it is clear that operating costs will differ substantially only in the area of steam costs vs power gas costs.

5.7 The Estimated Capital Costs

The estimated costs as developed for the above alternates are contained
in - Table 5.1 "Estimate of Capital Costs"
and - Table 5.2 "Estimate of Capital Costs with Electrical Ignitor"

A summary of the items which are contained in the major cost categories is presented in Table 5.5 "Items Included in Costs".

Although the Inquiry Package allowed 15 psig pressure buildup, the capital costs for Alternates 3, 4 and 5 have been adjusted to provide for a system which will not cause more than 10 psig pressure at the base of the stack. This has been done to reflect a more desirable and a more comparable system in terms of effect on the upstream plant in that the pressure build up in the systems is lower and similar to that of the other alternates.

5.8 Other Sized Plants

The comparable cost of flare systems for plants which differ in capacity from that of the typical plant is presented in:

- Table 5.3 Flare Systems for Various Sized Plants

These flare systems are considered to be identical in configuration to that of the typical plant.

The costs are based upon size factors which are applicable to such an estimate.

5.9 The Staged Multi-Point Open Ground Flare

A ground flare cannot be used for our typical plant due to H_2S content. However, in the context of flare system reviews, it was believed desirable to see how the costs of such a system would compare to an elevated flare. It was assumed that the flared streams of the typical plant contained no H_2S and a cost was developed for two flare systems. The costs as presented are based upon discussions with vendors, no inquiry information was issued.

Alternate G-1

Has the smokeless rate of the typical plant going to a ground flare at grade (4 stages) and the balance to a 5th stage which is an elevated utility flare similar to that of Alternate 1.A.

Alternate G-2

Has the entire waste gas stream going to the ground flare through seven stages (all at grade level).

See Table 5.4 Cost of Ground Flares

5.10 Small Oil Battery Flare Systems

Crude oil is produced into batteries wherein it is processed and separated from solution gas. The amount of solution gas varies considerably and may be up to a thousand or even more standard cubic feet per bbl of oil. The amount of solution gas separated is often not economical to recover and hence it is disposed of through a flare stack to atmosphere.

The source of gas is nominally from separators, treaters, oil boots, stock tanks, and waste water disposal tanks. The lowest pressure at the source is from the tanks and usually is not greater than approximately 0.5 psig unless a vapour recovery compressor is utilized.

Estimated capital costs for such a flare system have been developed as indicated in Table 5.6.

The configuration of the flare system is similar to that of Fig. 5.0 but scaled down appropriately. Other configurations may be used which may result in different costs of the "Other Battery Limits Items"; however, the relative costs of stack and tip will not vary significantly.

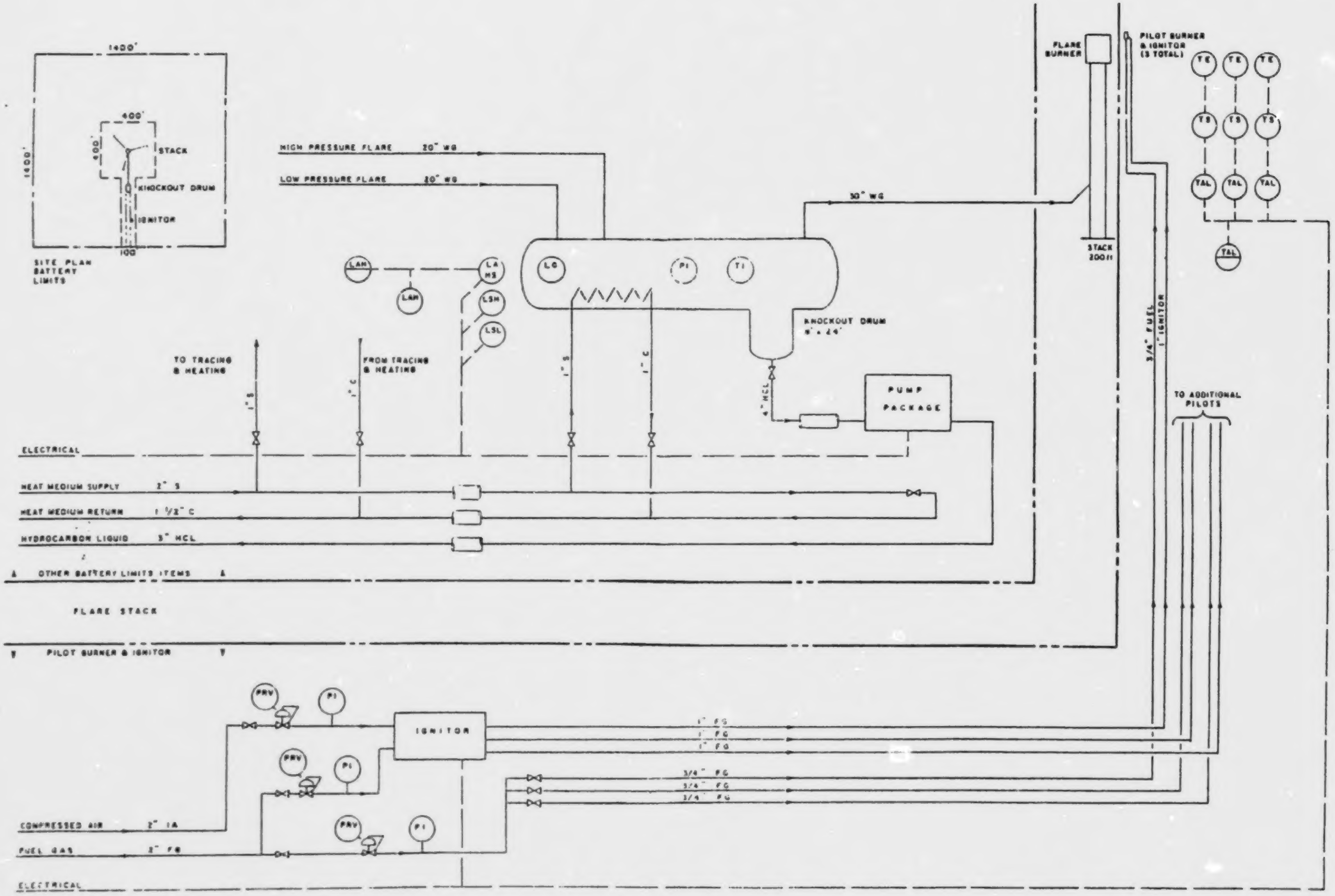
The costs, as contained in Table 5.6, are collected in categories as indicated in and as applicable from Table 5.5.

The table presents estimated capital costs for a 4", a 3" and a 2" System all with 40 foot stacks. The capacities indicated are based upon maximum pressures in the stock tanks of approximately 0.5 psig. The capacities would be considerably greater if this were not the restriction.

The 4" System is presented with alternate flare tips to illustrate the magnitude of difference between them.

The velocity jet option includes a vapour booster at the stock tank.

For approximations, the percentage variation as indicated for the 4" Stacks can also be applied to the 2" and 3" Stacks for various tips.


1400'
1400'
400'
400'
STACK
KNOCKOUT DRUM
IGNITOR
100
SITE PLAN BATTERY LIMITS
HIGH PRESSURE FLARE 20" WG
LOW PRESSURE FLARE 20" WG
30" WG
FLARE BURNER
STACK 200 ft
PILOT BURNER & IGNITOR (3 TOTAL)
TE
TS
TAL
LAH
LAH
LA HS
LSH
LSL
LG
PI
TI
KNOCKOUT DRUM 8' x 24'
4" HCL
PUMP PACKAGE
TO TRACING & HEATING
FROM TRACING & HEATING
1" S
1" C
3/4" FUEL
1" IGNITOR
TO ADDITIONAL PILOTS
ELECTRICAL
HEAT MEDIUM SUPPLY 2" S
HEAT MEDIUM RETURN 1 1/2" C
HYDROCARBON LIQUID 3" HCL
OTHER BATTERY LIMITS ITEMS
FLARE STACK
PILOT BURNER & IGNITOR
PRV
PI
IGNITOR
1" FG
3/4" FG
COMPRESSED AIR 2" IA
FUEL GAS 2" FG
ELECTRICAL

SCHEMATIC

UTILITY STACK

TYPICAL FLARE SYSTEM

FIG. 5.0

CAPITAL COST OF FLARES

TYPICAL LARGE PLANT

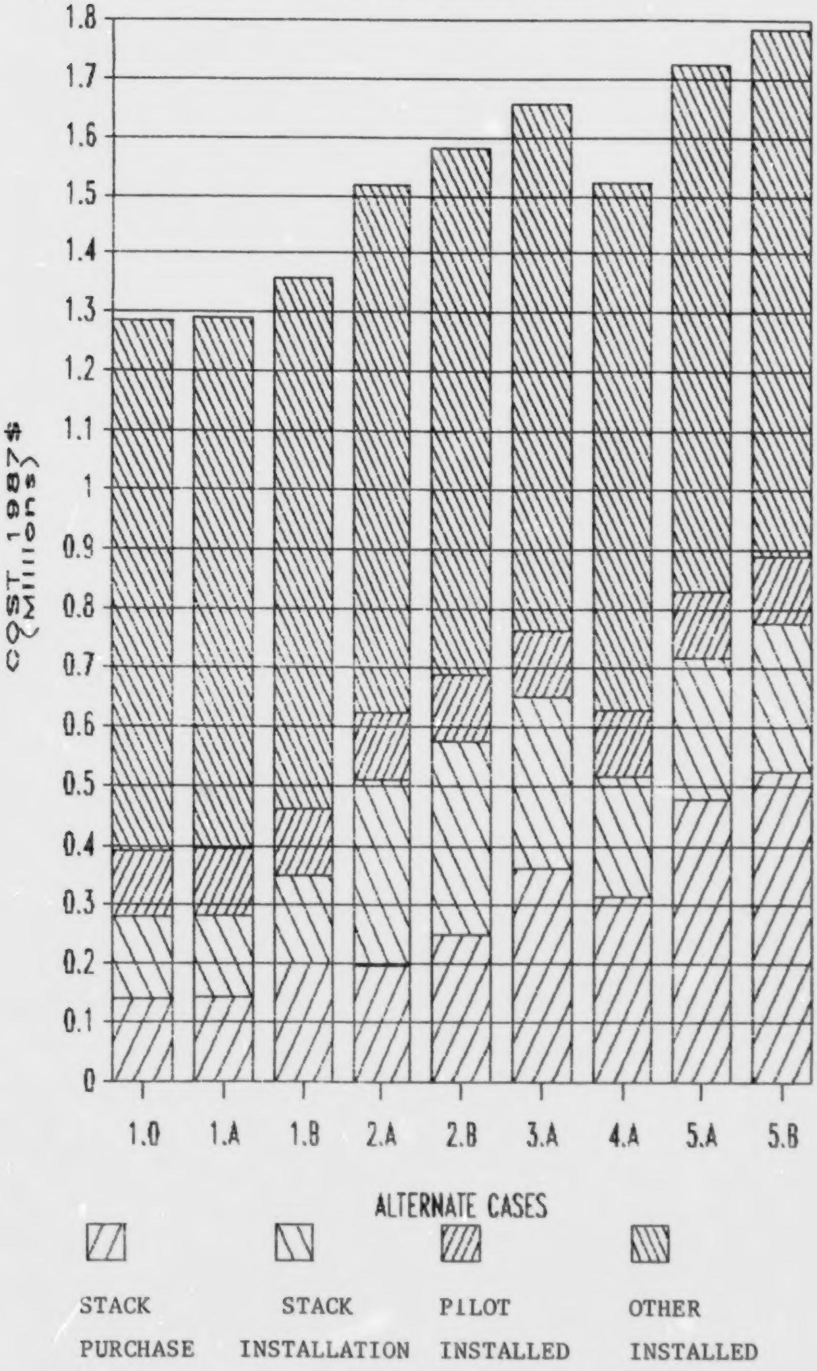


FIG. 5.1

FLARE SYSTEMS
ESTIMATE OF CAPITAL COSTS - TYPICAL LARGE PLANT

9.41.4
Table 5.1

	UTILITY			STEAM ASSIST		AIR ASSIST	MULTIPOINT	STAGED MULTIPOINT	
	Base Case 1.0 No Seal	1.A Vel Seal	1.B Den Seal	2.A Vel Seal	2.B Den Seal	3.A Vel Seal	4.A Vel Seal	5.A Vel Seal	5.B Den Seal
STACK									
Purchase	141,000	143,000	199,000	195,000	254,000	362,000	316,000	479,000	526,000
Difference with Base Case		2,000	58,000	54,000	113,000	221,000	175,000	338,000	385,000
Ratio with Base Case		1.01	1.41	1.38	1.80	2.57	2.24	3.40	3.73
Installation Cost	140,000	141,000	151,000	317,000	327,000	289,000	201,000	235,000	251,000
Difference with Base Case		1,000	11,000	177,000	187,000	149,000	61,000	95,000	111,000
Installed Cost	281,000	284,000	350,000	512,000	581,000	651,000	517,000	714,000	777,000
Difference with Base Case		3,000	69,000	231,000	300,000	370,000	236,000	433,000	496,000
Ratio with Base Case		1.01	1.25	1.82	2.07	2.32	1.84	2.54	2.77
	*	*	*	*	*	*	*	*	*
PILOT BURNER & IGNITOR									
Purchase Cost	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000
Installation Cost	98,000	98,000	98,000	98,000	98,000	98,000	98,000	98,000	98,000
Installed Cost	112,000	112,000	112,000	112,000	112,000	112,000	112,000	112,000	112,000
	*	*	*	*	*	*	*	*	*
OTHER BATTERY LIMIT ITEMS Knockout Drum, piping, sitework, etc.									
Installed Cost	894,000	894,000	894,000	894,000	894,000	894,000	894,000	894,000	894,000
Difference with Base Case		0	0	0	0	0	0	0	0
	*	*	*	*	*	*	*	*	*
BATTERY LIMIT FLARE SYSTEM TOTAL INSTALLED COST	1,287,000	1,290,000	1,356,000	1,518,000	1,587,000	1,657,000	1,523,000	1,720,000	1,783,000
Difference with Base Case		3,000	69,000	231,000	300,000	370,000	236,000	433,000	496,000
Ratio with Base Case		1.00	1.05	1.18	1.23	1.29	1.18	1.34	1.39
NOTES:				(1) Equal to some 1,500,000	(1)	(2) Equal to some 200,000			
	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)

NOTES:
(1) Capital Cost of steam generation or equal is not included
(2) Capital Cost of electrical generation or equal is not included
(3) Add to Other Battery Limit Items of all alternates for Water Seals if desired @ $55,000

Table 5.2

FLARE SYSTEMS
ESTIMATE OF CAPITAL COSTS WITH ELECTRICAL IGNITOR - TYPICAL LARGE PLANT

	UTILITY			STEAM ASSIST		AIR ASSIST	MULTIPOINT	STAGED MULTIPOINT	
	Base Case 1.0 No Seal	1.A Vel Seal	1.B Den Seal	2.A Vel Seal	2.B Den Seal	3.A Vel Seal	4.A Vel Seal	5.A Vel Seal	5.B Den Seal
STACK									
Purchase	141,000	143,000	199,000	195,000	254,000	362,000	316,000	479,000	526,000
Difference with Base Case		2,000	58,000	54,000	113,000	221,000	175,000	338,000	385,000
Ratio with Base Case		1.01	1.41	1.38	1.80	2.57	2.24	3.40	3.73
Installation Cost	140,000	141,000	151,000	317,000	327,000	289,000	201,000	235,000	251,000
Difference with Base Case		1,000	11,000	177,000	187,000	149,000	61,000	95,000	111,000
Installed Cost	281,000	284,000	350,000	512,000	581,000	651,000	517,000	714,000	777,000
Difference with Base Case		3,000	69,000	231,000	300,000	370,000	236,000	433,000	496,000
Ratio with Base Case		1.01	1.25	1.82	2.07	2.32	1.84	2.54	2.77
	*	*	*	*	*	*	*	*	*
ELECTRICAL IGNITOR SYSTEM (4)									
Purchase Cost	62,000	62,000	62,000	62,000	62,000	68,000	68,000	68,000	68,000
Installation Cost	29,000	29,000	29,000	29,000	29,000	53,000	53,000	53,000	53,000
Installed Cost	91,000	91,000	91,000	91,000	91,000	121,000	121,000	121,000	121,000
	*	*	*	*	*	*	*	*	*
OTHER BATTERY LIMIT ITEMS Knockout Drum, piping, sitework, etc.									
Installed Cost	894,000	894,000	894,000	894,000	894,000	894,000	894,000	894,000	894,000
Difference with Base Case		0	0	0	0	0	0	0	0
	*	*	*	*	*	*	*	*	*
BATTERY LIMIT FLARE SYSTEM TOTAL INSTALLED COST	1,266,000	1,269,000	1,335,000	1,497,000	1,566,000	1,666,000	1,532,000	1,729,000	1,792,000
Difference with Base Case		3,000	69,000	231,000	300,000	400,000	266,000	463,000	526,000
Ratio with Base Case		1.00	1.05	1.18	1.24	1.32	1.21	1.37	1.42
NOTES:				(1) Equal to some 1,500,000	(1)	(2) Equal to some 200,000			
	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
						(4)	(4)	(4)	(4)

NOTES:
(1) Capital Cost of steam generation or equal is not included
(2) Capital Cost of electrical generation or equal is not included
(3) Add to Other Battery Limit Items of all alternates for Water Seals if desired @ $55,000
(4) Pilot Gas Assist is added to alternates 3, 4 & 5

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FLARE SYSTEMS
ESTIMATE OF CAPITAL COSTS
VARIOUS SIZED PLANTS

9.41.4
Table 5.3

PLANT SIZE	INSTALLED COST	UTILITY 1.A Vel Seal	STEAM ASSIST 2.A Vel Seal	AIR ASSIST 3.A Vel Seal	MULTI-POINT 4.A Vel Seal	STAGED MULTI-POINT 5.A Vel Seal
TYPICAL	Stack	284,000	512,000	651,000	517,000	714,000
LARGE PLANT	Pilot	112,000	112,000	112,000	112,000	112,000
350 mmscfd	Other	894,000	894,000	894,000	894,000	894,000
350	Total	1,290,000	1,518,000	1,657,000	1,523,000	1,720,000
MEDIUM	Stack	101,833	183,587	233,428	185,380	256,018
PLANT	Pilot	49,778	49,778	49,778	49,778	49,778
80 mmscfd	Other	244,236	244,236	244,236	244,236	244,236
80	Total	395,848	477,601	527,442	479,394	550,032
SMALL	Stack	33,944	61,196	77,809	61,793	85,339
PLANT	Pilot	18,667	18,667	18,667	18,667	18,667
20 mmscfd	Other	91,589	91,589	91,589	91,589	91,589
20	Total	144,200	171,451	188,065	172,049	195,595

ESTIMATE OF CAPITAL COSTS
GROUND FLARES
for TYPICAL LARGE PLANT

9.41.4
Table 5.4

	GROUND FLARE for SMOKELESS RATE	PLUS UTILITY FLARE for BALANCE 1.A	EQUALS G.1 FLARE SYSTEM	G.2 GROUND FLARE SMOKELESS ALL RATES
FLARE (Stack)				
Vendor Supplied	274,000	123,000	397,000	1,096,000
Install	159,000	122,000	281,000	636,000
Installed	433,000	245,000	678,000	1,732,000
PILOTS & IGNITOR				
Vendor Supplied	18,000	14,000	32,000	32,000
Install	67,000	98,000	165,000	165,000
Installed	85,000	112,000	197,000	197,000
OTHER				
Installed	0	894,000	894,000	894,000
TOTAL	518,000	1,251,000	1,769,000	2,823,000

ITEMS INCLUDED IN CAPITAL COSTS

9.41.4

Table 5.5

STACK COMPONENT Purchase Costs Items	ALTERNATE 1.0	1.A	1.B	2.A	2.B	3.A	4.A	5.A	5.B
Ladders and Platforms	✓	✓	✓	✓	✓	✓	✓	✓	✓
Guy Wires	✓	✓	✓	✓	✓	✓	✓	✓	✓
Waste Gas Duct/s	✓	✓	✓	✓	✓	✓	✓	✓	✓
Air Duct	-	-	-	-	-	✓	-	-	-
Air Blower and Motor	-	-	-	-	-	✓	-	-	-
Miscellaneous Trim Hardware	✓	✓	✓	✓	✓	✓	✓	✓	✓
Packaged Control Stations for									
Steam Assist	-	-	-	✓	✓	-	-	-	-
Air Assist	-	-	-	-	-	✓	-	-	-
Staged Waste Gas	-	-	-	-	-	-	-	✓	✓
Steam Piping for Steam Assist	-	-	-	✓	✓	-	-	-	-
Flare Burners	✓	✓	✓	✓	✓	✓	✓	✓	✓
Velocity Seal	-	✓	-	✓	-	✓	✓	✓	-
Density Seal	-	-	✓	-	✓	-	-	-	✓
Shipping and Handling	✓	✓	✓	✓	✓	✓	✓	✓	✓

Installation Costs Items: Foundations, labour, machinery, electrical, etc. to install above materials including overhead and engineering costs

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PILOT BURNER & IGNITOR	Fuel Gas Alternate	Electrical Alternate
Purchase Costs	Burners & Flame Front Generator Package	Continuous Spark & Ignitor Package c/w Retractable Equipment
Installation Costs	Materials & Labour for air and fuel gas piping and all other installation including overhead and engineering	Materials & Labour for electrical supply and all installation including overhead and engineering and modification to flare burners

---

OTHER BATTERY LIMITS ITEMS

Installed Cost: Provides for all costs to provide this component, including all materials, labour, overhead, engineering, etc. for:

Knockout Drums, Waste Gas Piping, Liquid Pumps, Liquid Piping, Foundations, Structural Steel, Site Work, Shelters, Heat, Light, etc.

Table 5.6

SMALL OIL BATTERY FLARE SYSTEMS

ESTIMATE OF CAPITAL COSTS

SIZE	4" NOMINAL SYSTEM				3" NOMINAL TO	2" NOMINAL TO
CAPACITY	TO 800,000 SCFD				450,000 SCFD	50,000 SCFD
TYPE	Utility	Air Assist	Velocity Jet (1)	Flare Tip Incinerator (2)	Utility	Utility
STACK Installed Cost	4,000	20,000	16,000	19,000	3,400	2,700
* PILOT BURNER & IGNITOR Installed Cost	5,200	5,200	5,200	5,200	5,200	5,200
OTHER BATTERY LIMITS ITEMS Knockout Drums Pumps Piping Site work, etc.	33,000	33,000	33,000	33,000	28,000	23,000
BATTERY LIMITS FLARE SYSTEM TOTAL INSTALLED COST	42,200	55,200	54,200	57,200	36,600	30,900
RATIO TO BASE	1.0	1.31	1.28	1.36	.87	.73
DIFFERENCE FROM BASE		13,000	12,000	15,000	(5,600)	(11,300)

* This is a minimum type burner ignitor system. These systems can be considerably more costly depending upon the desired complexity. Automatic monitoring, relight, remote light, etc.

All stacks are 40 foot minimum.

(1) Single tip of type used in multi-point flares.

(2) See Figure 4.10.

6.0 OPERATING COSTS

6.1 General

Estimates of the annual operating costs for the flare systems which are described in Part 5.0 have been made and are presented in:

Table 6.1 - Summary of Annual Operating Costs
Table 6.2 - Summary of Annual Operating Costs with Electronic Ignitor
Table 6.3 - Summary of Annual Operating Costs for Various Sized Plants
Table 6.4 - Summary of Annual Operating Costs for Ground Flares

For this study operating costs are considered to consist of two types of costs:

1) Those costs which are determined as a percentage of capital invested.
    Direct Operating Costs (DOC)
    - Cost of operators, maintenance and repairs and similar
    Indirect Operating Costs (IOC)
    - Cost of taxes and insurance
    Cost of Capital (COC)
    - Depreciation and Return on Capital

2) Those costs which are based on the amount of a commodity used.
    - Electrical Energy
    - Fuel Gas
    - Steam

The unit costs used are:

Electrical - 3¢ per kW hr
Fuel gas - $1.50 per mcf approximately $28.50 per 1000 lbs.
($1.42 per GJ) ($62.83 per 1000 kg)
Steam - $4.00 per 1000 lbs
($8.82 per 1000 kg)

6.2 High Pressure Gas Assist

In estimating the amount of High Pressure gas demand it is common to use a factor where the weight of gas is 1.5 times the weight of steam which would be required.

To obtain operating costs for a High Pressure gas system the value of Alternate 2 can be used by the addition of the cost of the gas which is in excess of the cost of the steam i.e.

Add: Cost of Gas - Cost of Steam

$$\text{Cost of Gas/Cost of Steam} = \frac{1.5 \times 28.50}{4.00} = 10.7$$

$$= 9.7 \times \text{Cost of Steam}$$

6.3 Comments on Tables

6.3.1 Purge Gas

In the matter of purge gas used in connection with the density seal alternates

- to reduce oxygen upstream of the seal, purge rates can be low.
- low purge rates result in burnback of the burner.
- some vendors offer a burner which will effectively reduce burnback at the burner at the low purge rates.

In this presentation capital costs have allowed for the flare stacks to be so equipped and the lower purge rates are used.

Whereas the cost of purge gas is significant, when actively pursuing the installation of a flare system, purge gas requirements should be stressed and clarified prior to the completion of a final design.

TYPICAL LARGE PLANT

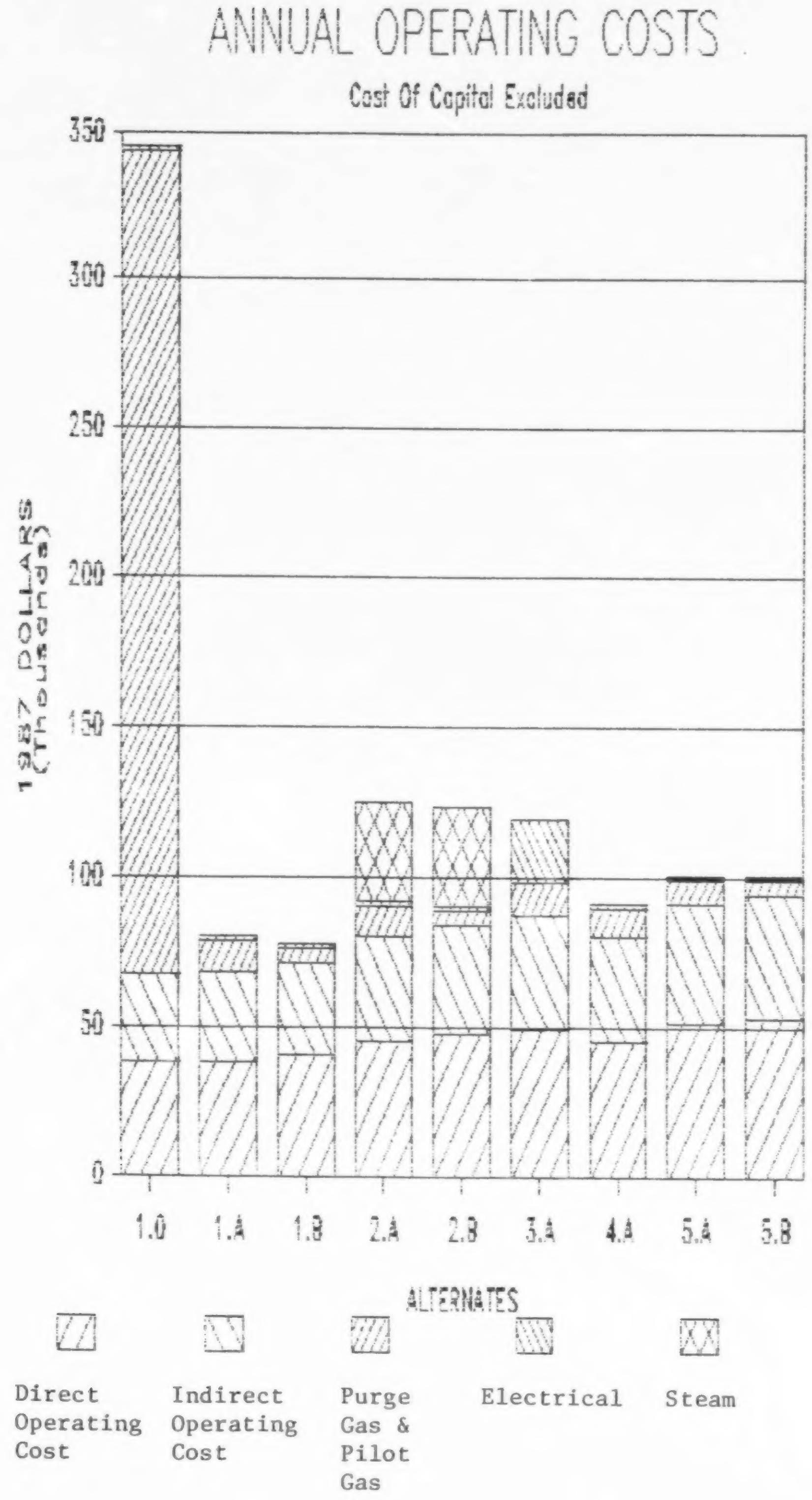

FIG. 6.1

Table 6.1

FLARE SYSTEMS
SUMMARY OF ANNUAL OPERATING COSTS - TYPICAL LARGE PLANT

	UTILITY			STEAM ASSIST		AIR ASSIST	MULTIPOINT	STAGED MULTIPOINT	
	Base Case 1.0 No Seal	1.A Vel Seal	1.B Den Seal	2.A Vel Seal	2.B Den Seal	3.A Vel Seal	4.A Vel Seal	5.A Vel Seal	5.B Den Seal
Capital Costs = C =	1,287,000	1,290,000	1,356,000	1,518,000	1,587,000	1,657,000	1,523,000	1,720,000	1,783,000
Direct Operating Costs									
Operators, Maintenance & Repairs									
Misc. = 3% of C	38,610	38,700	40,680	45,540	47,610	49,710	45,690	51,600	53,490
Indirect Operating Costs									
Ins.& Taxes = 1.8% of C	23,166	23,220	24,408	27,324	28,566	29,826	27,414	30,960	32,094
O/H = 10% x 4.8% of C	6,178	6,192	6,509	7,286	7,618	7,954	7,310	8,256	8,558
Sub Total	29,344	29,412	30,917	34,610	36,184	37,780	34,724	39,216	40,652
ADD									
Electrical Costs									
Pumps, Power, Ignitor	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
Blower						20,000			
Sub Total	1,300	1,300	1,300	1,300	1,300	21,300	1,300	1,300	1,300
Fuel Gas									
Pilot Gas	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Purge Gas	274,000	8,800	3,400	8,800	3,400	8,800	7,700	6,600	3,400
Sub Total	275,600	10,400	5,000	10,400	5,000	10,400	9,300	8,200	5,000
Steam Costs				33,000	33,000				
ANNUAL OPERATING COSTS									
Cost of Capital Excluded	344,854	79,812	77,897	124,850	123,094	119,190	91,014	100,316	100,442
Difference with Base Case		(265,042)	(266,957)	(220,003)	(221,760)	(225,664)	(253,839)	(244,538)	(244,411)
Ratio with Base Case	1	0.23	0.23	0.36	0.36	0.35	0.26	0.29	0.29
Ratio with 1.A Case	4.32	1.00	0.98	1.56	1.54	1.49	1.14	1.26	1.26
Cost of Capital									
Depreciation = 5% of C	64,350	64,500	67,800	75,900	79,350	82,850	76,150	86,000	89,150
Return of Cap.= 15% of C	193,050	193,500	203,400	227,700	238,050	248,550	228,450	258,000	267,450
Sub Total	257,400	258,000	271,200	303,600	317,400	331,400	304,600	344,000	356,600
Cost of Capital Included	602,254	337,812	349,097	428,450	440,494	450,590	395,614	444,316	457,042

ENVC42

9.41.4
Table 6.2

FLARE SYSTEMS
SUMMARY OF ANNUAL OPERATING COSTS WITH ELECTRONIC IGNITOR - TYPICAL LARGE PLANT

	UTILITY			STEAM ASSIST		AIR ASSIST	MULTIPOINT	STAGED MULTIPOINT	
	Base Case 1.0 No Seal	1.A Vel Seal	1.B Den Seal	2.A Vel Seal	2.B Den Seal	3.A Vel Seal	4.A Vel Seal	5.A Vel Seal	5.B Den Seal
Capital Costs = C =	1,266,000	1,269,000	1,335,000	1,497,000	1,566,000	1,666,000	1,532,000	1,729,000	1,792,000
Direct Operating Costs									
Operators, Maintenance & Repairs									
Misc. = 3% of C	37,980	38,070	40,050	44,910	46,980	49,980	45,960	51,870	53,760
Indirect Operating Costs									
Ins.& Taxes = 1.8% of C	22,788	22,842	24,030	26,946	28,188	29,988	27,576	31,122	32,256
O/H = 10% x 4.8% of C	6,077	6,091	6,408	7,186	7,517	7,997	7,354	8,299	8,602
Sub Total	28,865	28,933	30,438	34,132	35,705	37,985	34,930	39,421	40,858
ADD									
Electrical Costs									
Pumps, Power, Ignitor	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
Blower						20,000			
Sub Total	1,800	1,800	1,800	1,800	1,800	21,800	1,800	1,800	1,800
Fuel Gas									
Pilot Gas	0	0	0	0	0	200	200	200	200
Purge Gas	274,000	8,800	3,400	8,800	3,400	8,800	7,700	6,600	3,400
Sub Total	274,000	8,800	3,400	8,800	3,400	9,000	7,900	6,800	3,600
Steam Costs				33,000	33,000				
ANNUAL OPERATING COSTS									
Cost of Capital Excluded	342,645	77,603	75,688	122,642	120,885	118,765	90,590	99,891	100,018
Difference with Base Case		(265,042)	(266,957)	(220,003)	(221,760)	(223,880)	(252,055)	(242,754)	(242,627)
Ratio with Base Case	1.00	0.23	0.22	0.36	0.35	0.35	0.26	0.29	0.29
Ratio with 1.A Case	4.42	1.00	0.98	1.58	1.56	1.53	1.17	1.29	1.29
Cost of Capital									
Depreciation = 5% of C	63,300	63,450	66,750	74,850	78,300	83,300	76,600	86,450	89,600
Return of Cap.= 15% of C	189,900	190,350	200,250	224,550	234,900	249,900	229,800	259,350	268,800
Sub Total	253,200	253,800	267,000	299,400	313,200	333,200	306,400	345,800	358,400
Cost of Capital Included	595,845	331,403	342,688	422,042	434,085	451,965	396,990	445,691	458,418

Table 6.3

FLARE SYSTEMS
SUMMARY OF ANNUAL OPERATING COSTS
VARIOUS SIZED PLANTS

	UTILITY	STEAM ASSIST	AIR ASSIST	MULTIPOINT	STAGED MULTIPOINT
	1.A Vel Seal	2.A Vel Seal	3.A Vel Seal	4.A Vel Seal	5.A Vel Seal
TYPICAL LARGE PLANT					
Capital Costs = C =	1,290,000	1,518,000	1,657,000	1,523,000	1,720,000
Operating Costs					
All at 5.28 % of C	68,112	80,150	87,490	80,414	90,816
ADD					
Electrical Costs					
Pumps, Power, Ignitor	1,300	1,300	1,300	1,300	1,300
Blower			20,000		
Fuel Gas					
Pilot Gas	1,600	1,600	1,600	1,600	1,600
Purge Gas	8,800	8,800	8,800	7,700	6,600
Steam Costs		33,000			
ANNUAL OPERATING COSTS					
Cost of Capital Excluded	79,812	124,850	119,190	91,014	100,316
Cost of Capital					
all at 20% of C	258,000	303,600	331,400	304,600	344,000
Cost of Capital Included	337,812	428,450	450,590	395,614	444,316
MEDIUM PLANT					
Capital Costs = C =	395,848	477,601	527,442	479,394	550,032
Operating Costs					
All at 5.28 % of C	20,901	25,217	27,849	25,312	29,042
ADD					
Electrical Costs					
Pumps, Power, Ignitor	1,000	1,000	1,000	1,000	1,000
Blower			4,571		
Fuel Gas					
Pilot Gas	1,000	1,000	1,000	1,000	1,000
Purge Gas	2,000	2,000	2,000	1,800	1,500
Steam Costs		7,543			
ANNUAL OPERATING COSTS					
Cost of Capital Excluded	24,901	36,760	36,420	29,112	32,542
Cost of Capital					
all at 20% of C	79,170	95,520	105,488	95,879	110,006
Cost of Capital Included	104,070	132,280	141,909	124,991	142,548
SMALL PLANT					
Capital Costs = C =	144,200	171,451	188,065	172,049	195,595
Operating Costs					
All at 5.28 % of C	7,614	9,053	9,930	9,084	10,327
ADD					
Electrical Costs					
Pumps, Power, Ignitor	800	800	800	800	800
Blower			1,100		
Fuel Gas					
Pilot Gas	500	500	500	500	500
Purge Gas	500	500	500	400	400
Steam Costs		2,000			
ANNUAL OPERATING COSTS					
Cost of Capital Excluded	9,414	12,853	12,830	10,784	12,027
Cost of Capital					
all at 20% of C	28,840	34,290	37,613	34,410	39,119
Cost of Capital Included	38,254	47,143	50,443	45,194	51,146

FLARE SYSTEMS
SUMMARY of ANNUAL OPERATING COSTS
GROUND FLARES - TYPICAL LARGE PLANT

9.41.4
Table 6.4

	UTILITY FLARE		GROUND FLARE	
	Base Case 1.0 No Seal	1.A Vel Seal	G.1 Grade & Elev.	G.2 @ Grade
Capital Costs = C =	1,287,000	1,290,000	1,769,000	2,823,000
Direct Operating Costs				
Operators, Maintenance & Repairs				
Misc. = 3% of C	38,610	38,700	53,070	84,690
Indirect Operating Costs				
Ins.& Taxes = 1.8% of C	23,166	23,220	31,842	50,814
O/H = 10% x 4.8% of C	6,178	6,192	8,491	13,550
Sub Total	29,344	29,412	40,333	64,364
ADD				
Electrical Costs				
Pumps, Power, Ignitor	1,300	1,300	1,300	1,300
Blower				
Sub Total	1,300	1,300	1,300	1,300
Fuel Gas				
Pilot Gas	1,600	1,600	3,700	3,700
Purge Gas	274,000	8,800	9,300	500
Sub Total	275,600	10,400	13,000	4,200
Steam Costs				
ANNUAL OPERATING COSTS				
Cost of Capital Excluded	344,854	79,812	107,703	154,554
Difference with Base Case		(265,042)	(237,150)	(190,299)
Ratio with Base Case	1.00	0.23	0.31	0.45
Ratio with 1.A Case	4.32	1.00	1.35	1.94
Cost of Capital				
Depreciation = 5% of C	64,350	64,500	88,450	141,150
Return of Cap.= 15% of C	193,050	193,500	265,350	423,450
Sub Total	257,400	258,000	353,800	564,600
Cost of Capital Included	602,254	337,812	461,503	719,154

Table 6.5

SMALL OIL BATTERY FLARE SYSTEMS

ANNUAL OPERATING COSTS

SIZE	4" NOMINAL SYSTEM				3" NOMINAL	2" NOMINAL
CAPACITY	TO 800,000 SCFD				TO 450,000 SCFD	TO 50,000 SCFD
TYPE	Utility	Air Assist	Velocity Jet	Flare Tip Incinerator	Utility	Utility
CAPITAL COSTS = C	42,200	55,200	54,200	57,200	36,600	30,900
OPERATING COSTS						
Direct & Indirect @ 5.28% x C	2,230	2,900	2,860	3,020	1,930	1,630
ADD						
Elecctrical Costs						
Pump Power	380	380	380	380	300	200
Blower		950	300			
Fuel Gas						
Pilot	300	300	300	300	300	300
Purge	Not Applicable					
TOTAL ANNUAL OPERATING CAPITAL EXCLUDED	2,910	4,530	3,840	3,700	2,530	2,130
RATIO TO BASE	1.0	1.56	1.32	1.27	0.87	0.73
DOLLAR DIFFERENCE	0	1,620	930	790	(380)	(780)
COST OF CAPITAL @ 20% OF C	8,440	11,040	10,840	11,440	7,320	6,180
TOTAL	11,350	15,570	14,680	15,140	9,850	8,310
RATIO TO BASE		1.37	1.29	1.33	0.87	0.73
DOLLAR DIFFERENCE		4,220	3,330	3,790	(1,500)	(3,040)

7.0 REVIEW OF FLARE SYSTEM FEATURES

A review has been made of the information which has been presented by various vendors relative to the "Flare Systems" which may be used in the typical plant.

A summary of the information is presented in Tables 7.1 through 7.4.

Comments on the tabulated information follow as is applicable to each flare system and as it may perform in the typical plant.

Alternate 1 - Utility Stack

- The demand for purge gas is high when no seals are used.
- The demand for purge gas is much lower when velocity seals are used.
- The demand for purge gas indicated differs considerably when density seals are used.

  Very low rates of purge gas are attainable with density seals if burnback at the flare tip is ignored or if special flare burners are installed to prevent burnback.
- It would be expected that undesirable smoke emissions would occur at most times if any of the arrangements under Alternate 1 were to be used.

Alternate 2 - Smokeless Steam Assist

- Higher steam flows are required when lower pressures are used.
- The actual pressure at which steam would be available depends upon plant detail design and steam balance.
- When a steam system is used at a gas plant it is not unusual for excess steam to be available at 35 psig (241 kPa).
- Vendors prefer steam at some 100 psig (689 kPa).

Alternate 3 - Smokeless Air Assist

- Flow velocities vary from 0.54 to 1.13 mach. (The 1.13 mach is a superficial velocity not an actual velocity.)
- Noise levels vary from 85 to 133 dBA. The high value of 133 dBA results from the high burner tip exit velocities which are used.
- Air requirements vary from 7 000 to 94 000 scfm. (198 - 2655 m^3/min) The 94 000 scfm is a nominal amount based on a fraction of the air required for stoichiometric air to burn the desired streams.
  The 7 000 scfm is similarly derived, however, credit is taken for a large portion of this combustion air being induced by the higher pressure drop across the nozzles and only the balance is provided by the air blower.
- Power requirements vary from 45 Hp to 250 Hp. (34 - 186 kW)

Alternate 4A - Smokeless Multi-point

This alternate takes advantage of the high pressure drop available at the high flow rates. The air introduced by the high jet velocity is expected to produce smokeless burning at the higher flow rates. It is not expected that at low flow rates that sufficient air would be available to prevent the formation of smoke.
It would be expected that undesirable smoke emissions would occur at most times if this arrangement were used.

Alternate 5 - Smokeless - Staged Multi-point

- Flow velocities vary from .48 mach to 1.13 mach.
  (The 1.13 mach is a superficial velocity not an actual velocity)
- Noise levels vary from 85 dBA to 133 dBA.
- It has been suggested that because of the additional items of hardware which are utilized that maintenance costs are relatively higher than other systems.
- A failure of hardware (control valves, burner heads, etc.) which do not exist in the other systems could have a greater negative effect on plant operations.

Alternate 5 - Smokeless - Staged Multi-point (cont'd)

- This flare system could be made essentially smokeless throughout the range of expected flows with the addition of nozzles.
- The smokeless part of this system differs in principle from the others in that it disperses the gases to be burned into the air as opposed to inducing the air into the gases for burning.

Pilot Burner & Ignitor

All flare systems in the tabulation utilize three fuel gas pilot burners and a flame front generator as an ignitor.

Electrical pilot systems are available which provide:

- a spark ignition system
- a continuous electrical spark
- retractable features

These are readily installed in flare systems Alternate 1 and Alternate 2. With the addition of a gas pilot assist the electrial ignitor can be adapted to the remaining alternates should this be desirable.

Table 7.1

RANGE OF VENDOR INFORMATION UTILITY FLARE

		No Seals			With Velocity Seal			With Density Seal		
			1.0			1.A			1.B	
Internal Diameter										
Nominal	inches	35	to	42	35	to	42	35	to	42
Effective	inches	32	to	42	32	to	42	32	to	42
Exit Velocity										
	fps	517	to	600	517	to	600	517	to	600
	mach	.42	to	.48	.42	to	.64	.42	to	.48
Moving Parts			No			No			No	
Internal Refractory			Yes		No	&	Yes		Yes	
External Refractory			No			No			No	
Pressure at Base	psig	3.5	to	5	3.9	to	5.2	3.9	to	7.8
Noise Level	dBA	85	to	91	85	to	91	85	to	91
Maximum Radiation	btu/hr sq ft	1,500	to	1,600	1,480	to	1,600	1,500	to	1,600
Purge Gas Rate	scfd	280,000	to	600,000	14,000	to	32,000	6,000*	to	504,000
Pilot Gas Rate	scfd	1,200	to	5,500	1,200	to	5,500	1,200	to	5,500
Combustion Efficiency	%	-	to	99+	-	to	99+	-	to	99+
Destruction Efficiency	%	-	to	99+	-	to	99+	-	to	99+
No_x Emissions	ppm	-	to	10	-	to	10	-	to	10

* This low flow rate will result in burnback
unless the Flare Burner is compatible

Table 7.2

RANGE OF VENDOR INFORMATION SMOKELESS - STEAM ASSIST

		With Velocity Seal			With Density Seal		
			2.A			2.B	
Internal Diameter							
Nominal	inches	35	to	42	35	to	42
Effective	inches	30	to	42	32	to	42
Exit Velocity							
	fps	517	to	794	517	to	600
	mach	.42	to	.64	.42	to	.48
Moving Parts			No			No	
Internal Refractory		Yes	&	No	Yes	&	No
External Refractory			No			No	
Pressure at Base	psig	3.9	to	5.2	3.9	to	7.8
Noise Level	dBA	85	to	92	85	to	92
Maximum Radiation	btu/hr sq ft	1,500	to	1,600	1,500	to	1,600
Purge Gas Rate	scfd	14,000	to	32,000	6,000*	to	500,000
Pilot Gas Rate	scfd	1,200	to	5,400	1,200	to	5,400
Combustion Efficiency	%	-	to	99+	-	to	99+
Destruction Efficiency	%	-	to	99+	-	to	99+
No_x Emissions	ppm	-	to	10	-	to	10
Steam Press	psig	35	to	100	35	to	100
Stream Rate	lbs/hr	30,000	to	40,000	30,000	to	40,000

* This low flow rate will result in burnback unless the Flare Burner is compatible

Table 7.3

RANGE OF VENDOR INFORMATION SMOKELESS FLARE

		Air Assisted	Multi-point
		With Velocity Seal	With Velocity Seal
		3.A	4.A
Internal Diameter			
Nominal	inches	35 to 36	35 to 36
Effective	inches	21 to 24	21 to 24
Exit Velocity			
	fps	658 to 1,400	1,100 to 1,400
	mach	.54 to 1.13	Up to 1.13
Moving Parts		No	No
Internal Refractory		No	No
External Refractory		No	No
Pressure at Base	psig	3 to 15	Up to 15
Noise Level	dBA	85 to 133	Up to 133
Maximum Radiation	btu/hr sq ft	1,300 to 1,600	
Purge Gas Rate	scfd	14,000 to 24,000	14,000
Pilot Gas Rate	scfd	1,200 to 5,500	3,200 to 5,000
Combustion Efficiency	%	- to 99+	Not Indicated
Destruction Efficiency	%	- to 99+	Not Indicated
No_x Emissions	ppm	Not Indicated	Not Indicated
Air Blower Rate	scfm	7,000 to 99,000	
Motor	H.P.	45 to 250	
Discharge Pressure	"W.C."	4" to 20"	

Table 7.4

RANGE OF VENDOR INFORMATION SMOKELESS - STAGED MULTI-POINT

		With Velocity Seal			With Density Seal		
		5.A			5.B		
Internal Diameter							
Nominal	inches	34	to	36	34	to	36
Effective	inches	(1) 10	to	(1) 12	(1) 10	to	12
		(2) 22	to	(2) 32	(2) 22	to	32
Exit Velocity							
	fps	1,000	to	1,400	1,000	to	1,400
	mach	(1) .82	to	1.13	(1) .82	to	1.13
		(2) .48			(2) .48		
Moving Parts		Staging Controls			Staging Controls		
Internal Refractory			No			No	
External Refractory			No			No	
Pressure at Base	psig	5(2)	to	15(1)	5(2)	to	15(1)
Noise Level	dBA	85	to	133	85	to	133
Maximum Radiation	btu/hr sq ft	1,400	to	1,500	1,400	to	1,500
Purge Gas Rate	scfd	700	to	18,000	*6,100	to	1,400
Pilot Gas Rate	scfd	1,200	to	3,200	1,200	to	3,200
Combustion Efficiency	%	-	to	99+	-	to	99+
Destruction Efficiency	%	-	to	99+	-	to	99+
No_x Emissions	ppm	Not Indicated			Not Indicated		

(1) Smokeless

(2) Balance

* This low flow rate will result in burnback unless the Flare Burner is compatible

8.0 COMPARATIVE TECHNICAL AND ECONOMIC ASSESSMENTS

8.1 Evolution of Flare Systems

The evolution of flare system design has progressed from the rudimentary open pipe ignited by burning arrows, Very pistols or shotguns, etc., in response to various safety, economic and environmental considerations. A primary concern is to keep the flare burning and this led to flame retention devices to prevent liftoff and/or blowout, continuous burning pilots with windshields and reliable remotely initiated ignition systems. The hazards of radiation and liquid carryover led to height and location criteria, and provision of adequate liquid knockout facilities.

Safety concerns also prompted the adoption of liquid seals and the use of adequate purge gas to prevent flashback. The former also find application as staging devices. Economic incentives then led to the development of purge reduction seals, and to the modification of flare tips to prevent or mitigate the effects of burn-back at low purge gas flows.

The above developments were primarily motivated by safety and economic considerations, but have indirectly resulted in better burner and burning characteristics, particularly insofar as they affect flame stability.

Environmental concerns prompted the development of smokeless flares. A smoking flame is an indication of incomplete combustion at least to the extent of the amount of soot formed. Experimental studies have shown that the opposite is not necessarily true. Flames free of visible smoke can release uncombusted gases as well as invisible carbon particles. In addition, even a smoking flame can have high gaseous (calculated on a soot-free basis) combustion efficiencies, in excess of 99% (304) (406). Initially developed smokeless flares were of the assisted type, utilizing various means to induce additional combustion air: steam, water, high pressure gas and low pressure air. More sophisticated designs evolved to reduce noise levels, particularly for steam assisted flares.

8.1 Evolution of Flare Systems (cont'd)

A more recent development is the staged multi-point flare, which provides smokeless combustion and lower radiation levels without external assist, by utilizing the energy of the waste gas to provide mixing and disperse the gas into the combustion air. The enclosed ground flare, utilizing this concept, provides invisible as well as smokeless combustion. The staged multi-point flare also is free of the problems of burn-back and flame pulldown.

The evolution of flare system design as outlined above has improved flare systems from the point of view of safety, maintenance costs, energy costs and environmental considerations, but capital costs have also increased in parallel with the improvements. Further, none of these developments have specifically addressed combustion efficiency, except to the extent that it has been perceived to be improved by the elimination of smoke. This is, no doubt, in large part due to the difficulties in obtaining meaningful measurements of combustion efficiencies in industrial flares.

8.2 Combustion and Destruction Efficiencies

Combustion efficiency is defined as the degree to which all fuel materials have been completely oxidized, hydrocarbons to CO_2, sulfur compounds to SO_2, etc. Destruction efficiency is a measure of the degree of destruction of the particular fuel material. It is equal to the combustion efficiency only when there are no incompletely burned intermediates, such as CO or soot in the case of hydrocarbons.

For flares the overall or "global" combustion efficiency, U, for hydrocarbons can be calculated on a carbon mass basis as follows:

$$U = \frac{C(in) - C(out)}{C(in)} \times 100$$

where: C(in) is the mass flow of carbon in the flared gas.

C(out) is the mass flow of carbon in unburned hydrocarbon, CO or soot in the plume.

8. 2 Combustion and Destruction Efficiencies (cont'd)

This sounds simple but it requires an accurate measurement of the plume velocity, including the dilution air, in order to measure mass flow (i.e. to close the mass balance). No one has yet succeeded in accomplishing this feat for flares, except for small, totally enclosed, laboratory flares where it is possible to measure the flow of incoming combustion air, as well as that of the flared gas.

The other approach to obtaining the overall combustion efficiency is via the measurement of local combustion efficiencies. This requires only local sample probe measurements of the plume constituents; mass flow measurements are not needed. The local efficiencies, E, can then be calculated by relating the amount of unburned and/or incompletely burned constituents to total constituents as follows:

For hydrocarbons:

$$E = \frac{[CO_2]}{[CO_2]+[CO]+[THC]+[Soot]} \times 100$$

For sulfur compounds:

$$E = \frac{[SO_2]}{[SO_2]+[H_2S]+[COS]+2[CS_2]} \times 100$$

where: square brackets denote mole percent
THC is total hydrocarbon measured as C_1

Provided the measurements are taken under relatively steady flame conditions (i.e. little or no wind), it is possible to calculate local plume velocities to match the local constituent concentrations, and thus local fluxes, which can be integrated to obtain the overall combustion efficiency.

8.3 Recent Flare Combustion Efficiency Studies

Most of the significant flare efficiency studies have been conducted since 1979. These studies have been motivated primarily by increasing environmental concern over the potential impact from flaring emissions. The work done up to 1983 has been reviewed by Dubnowski and Davis (406), and this has also been summarized by Leahey et al (301). Since that time the major research work has been the EPA/EER studies conducted by Energy and Environmental Research Corporation for the U.S. Environmental Protection Agency (305)(306)(308)(309).

This work has been done at a pilot flare testing facility especially designed and built for the purpose at Irvine, California. Pilot flare tip diameters normally employed ranged from 1.5 to 12 inches (38 to 305 mm), with smaller sizes for the laboratory scale flares. Gases and gas mixtures flared in pilot-scale tests include natural gas, ethylene, propane, propylene, refinery gas (50% hydrogen plus light hydrocarbons), hydrogen sulfide, ammonia, 1,3-butadiene, and ethylene oxide.

Results of these studies are being used as a data base for the promulgation of industrial flare practices and regulations. The key findings are:

- Flares can be operated with combustion and destruction efficiencies exceeding 98-99%.

- Flare efficiency depends on flame stability. A flare operated within the envelope of stable operating conditions will exhibit high efficiency unless too much steam or air assist is used. (The term "stable flame" means that a flame is maintained, and can include conditions where there is some degree of flame lift-off from the flare tip.)

- A flare operated outside its stable flame envelope becomes unstable; this can result in combustion and destruction efficiency below 98%.

- The stable flame operating envelope is specific to flare head design and gas composition.

- Operating conditions that have the largest influence on flame stability for a given flare head are the gas exit velocity and heating value. Depending on flare type, levels of steam, air, or pilot assist can also affect flame stability and destruction and combustion efficiency. Results also show that flare gases of equivalent heating value, but different composition, can have different stable flame operating envelopes when flared from the same flare.

The general test procedure included the initial establishment of test conditions. Then plume samples were collected for 20 minutes in order to time-average perturbations and collect sufficient amounts of sample for analysis. Samples were collected from five different radial locations, at a height above the flame experimentally determined to be beyond the flame envelope. If the probes were too high, air dilution of the samples reduced combustion product measurement. If the probes were located too low, inside the flame envelope, incompletely burned samples were collected. Local sample analyses, combined with velocities calculated from jet theory were integrated to calculate overall combustion efficiency.

Limitations inherent in the necessity for accurately locating the sample probes relative to the flare flame, and the methods of calculating local plume velocities in order to integrate the local fluxes into overall combustion efficiencies, precluded testing under wind conditions. Wind screens surrounded the test area, and tests were not conducted when the wind speed was greater than five mph (2.2 m/s). The EPA is not unaware of the deficiency imposed by this limitation, but foresees no way around this limitation with current state-of-the-art measurement techniques, and therefore has no current plans to attempt to measure combustion efficiencies in wind conditions.
(Bruce A. Tichenor, personal communication, March 1987).

The remote sensing of flare emissions is a possible alternative to direct sampling, but instrumentation and techniques for this purpose are as yet undeveloped (308)(310).

8.3 Recent Flare Combustion Efficiency Studies (cont'd)

The only reported studies measuring combustion efficiencies in wind conditions are those of Siegel [summarized by Dubnowski and Davis (406)], Leahey et al (301) and Colley et al (403). All three studies of necessity measured local combustion efficiencies.

Siegel (1980) used an array of 40 to 60 sample points to collect the off gases from a 15 feet (4.6 m) high, 8 inch (200 mm) diameter, steam assisted pilot-sized flare. Over 1300 data samples were collected investigating the effects of variable steam rates, flare gas densities and wind velocities, but only high heat content refinery gases (1500 BTU/SCF, 56 MJ/m^3) having high hydrogen content (approximately 50%) were tested. Since the measured local combustion efficiencies were consistently high, (usually over 99%) Siegel concluded that they were a valid indication of the overall combustion efficiency.

Leahey et al (1985) measured H_2S combustion efficiencies at an Alberta acid gas flare, with the acid gas diluted with varying amounts of fuel gas. The flare stack was 80 ft. (24 m) high and 4 inches (100 mm) in diameter. Wind velocities were light to moderate, varying from 2.5 mph (1.1 m/s) to 13.6 mph (6.1 m/s). In four valid tests local combustion efficiencies of 22, 89, 96 and 100 percent were measured.

Colley et al (1982) sampled solution gas flare stacks at a number of locations in the Redwater, Alberta oilfield. Typically these flares are 3 inch (76 mm) pipes with 1.5 inch (38 mm) orifice openings at the top. A 6 inch (150 mm) diameter by 12 inch (300 mm) long windshield is located at the top. Ignition is by electric spark ignitor. From the analytical data reported by Colley for two sites, local H_2S combustion efficiencies of 38 and 100 percent were calculated for one site, and 87%, 96% and 86% for the other site.

8.4 Combustion Efficiencies of Full Scale Industrial Flares

From the foregoing it is evident that while the EPA/EER studies on pilot flares have concluded that flares with stable flames can be operated with combustion efficiencies exceeding 98-99%, no definitive proven conclusions can be drawn regarding efficiencies of industrial flares subjected to the effects of:

(a) Winds
(b) Less than optimum control of smoke suppressant flows
(c) Scale-up considerations

However, some general observations can be made with respect to the various types of flares. Those whose efficiencies might be expected to be less adversely affected by winds are the low pressure air assisted flare and the staged multi-point flare. In the case of the low pressure air assisted flare the discharge velocity of the air at the flare burner tip is typically about 90 feet per second (27 m/s). With this high upward discharge velocity, the wind has less effect on the tilt of the flame. The smokeless flame from the air assisted burner tip is thus shorter, straighter and less luminous.

In the case of the staged multi-point flare, the ratio of the flare tip exit velocity to average wind speed is also maintained at a higher level, resulting in a shorter and overall wider flame in the elevated flare. The staged multi-point open ground flare will also be less exposed to the wind than an elevated flare, and the staged multi-point enclosed ground flare is relatively unaffected by wind.

The methods used to control the injection of smoke suppressants (usually steam or low pressure air assist), and the disadvantages of each, are discussed in some detail in Section 4.7.1. It is evident that these problems did not exist in the closely controlled conditions of the EPA/EER (and earlier) studies, where the flow rates and compositions of the flared gases were always well known. In the case of intermittent

8.4 Combustion Efficiencies of Full Scale Industrial Flares (cont'd)

emergency industrial flares, flow rates and often gas compositions are not normally known, and optimum control of smoke suppressant flows is difficult. This can result in poor combustion efficiency. This is not a problem, however, in the case of the unassisted utility and staged multi-point flares.

The pilot flare tip diameters used in the EPA/EER studies ranged from 1.5 to 12 inches (38 to 305 mm). Single point full scale industrial flare tip sizes range to 84 inches (2134 mm) in diameter or more. Staged multi-point flare tip sizes typically fall within the range of sizes used in the EPA/EER tests. Hence it might be expected that the combustion efficiency of this type of flare would be less likely to be adversely affected by scale-up considerations than the larger single point flares.

8.5 Best Available and Best Practical Technologies

For the reasons outlined in Section 8.4, this section does not address the subject of flare combustion efficiency in terms of best available or best practical technologies, since no definitive conclusions can be drawn in this regard. This section addresses other environmental, safety and reliability objectives in the design of flare systems, and the best available and best practical proven means of accomplishing these objectives.

These technology assessments are outlined in Tables 8.1 and 8.2 for sweet gas and sour gas, respectively. It should be noted that each performance objective is treated entirely separately, and the best means of achieving it is outlined. In an actual design case involving a number of performance objectives, the more rigorous requirements will govern.

Generally speaking, the best available technology is proven technology that will best meet the performance objective without regard for economics. The best practical technology is proven technology that takes

8.5 Best Available and Best Practical Technologies (cont'd)

into account economic considerations, generally on the basis that an intermittent flare will operate at more than 25 percent of its maximum capacity only a small percentage of the time. Where more than one technology will equally meet a performance objective, the lowest cost one is outlined in the tables.

The tables apply to all intermittent industrial flares in all industrial sectors including:
- natural gas processing
- refineries and oil upgrading facilities
- oil and bitumen production
- chemical manufacturing

They are also applicable to continuous flares, such as solution gas flares, with modifications under "best practical technology" to recognize that the more rigorous requirement would apply to 100 percent of capacity rather than 25 percent.

8.6 Economic Assessments

Detailed capital and operating costs are outlined in Sections 5.0 and 6.0, respectively, for various elevated and ground flaring systems for typical large, medium and small gas processing plants and for small oil production batteries. Capital costs are seen to climb more or less steadily from the simplest to the more sophisticated systems, whereas the annual operating costs (cost of capital excluded) remain more or less constant, after the dramatic drop from the base case, due to the saving in purge gas. Capital costs more than double over the range of cases shown in the tables.

8.6 Economic Assessments (cont'd)

Two additional capital cost estimates were made, which are not included in Section 5.0. These are for the "Cadillac" of flaring systems, the staged multi-point enclosed ground flare. For the typical large plant, with the enclosed ground flare at 25% of maximum capacity, plus a utility flare for the remaining 75%, the capital cost estimate is $3,636,000. For a staged multi-point enclosed ground flare for 100% of capacity, this capital cost jumps to $10,291,000.

With respect to the annual operating cost estimates, it should be noted that the energy costs assumed (for electricity, fuel gas and steam) will not necessarily fit the circumstances of all gas processing facilities, but the totals are easily adjusted to fit other energy cost figures. Similarly the criteria used to include the cost of capital in the annual operating costs are also subject to change, according to the economic criteria used by the various operating companies.

TABLE 8.1 TECHNOLOGY ASSESSMENTS SWEET GAS

Performance Objective	Best Available Technolgy (B.A.T.)	Best Practical Technolgy (B.P.T.)
Environmental:		
Smokeless (1)	Staged multi-point open ground flare	25% as in B.A.T. (2) 75% Elevated utility (3) flare
Low Noise	Utility flare	Utility flare
Low Visibility	Enclosed ground flare	25% as in B.A.T. (2) 75% Elevated utility (3) flare
Safety:		
No explosive mixture in flare system	Liquid seal plus density seal	Velocity seal
Low radiation	Enclosed ground flare	25% as in B.A.T. (2) 75% Elevated utility (3) flare
No liquid carryover	Liquid knockout plus remote location	As in B.A.T.
Dispersion of unignited gases	Elevated flare	Elevated flare
Reliability:		
Flame stability	Utility flare	Utility flare
Ignition systems	Continuous pilot Flame front ignition	As in B.A.T.
No burn-back or flame pulldown	Staged multi-point flare	Special design utility flare with velocity seal
Other:		
Minimum space requirement	Enclosed ground flare	Elevated flare

(1) Assumes smoking gases are flared.
(2) 25% of maximum emergency relief capacity.
(3) 75% of maximum emergency relief capacity.

TABLE 8.2 TECHNOLOGY ASSESSMENTS SOUR GAS

Performance Objective	Best Available Technolgy (B.A.T.)	Best Practical Technolgy (B.P.T.)
Environmental:		
Smokeless (1)	Staged multi-point elevated flare	25% as in B.A.T. (2) 75% Elevated utility (3) flare
Low Noise	Elevated utility flare	Elevated utility flare
Low Visibility	Elevated utility flare	Elevated utility flare
Safety:		
No explosive mixture in flare system	Liquid seal plus density seal	Velocity seal
Low radiation	Staged multi-point elevated flare	Elevated utility flare
No liquid carryover	Liquid knockout plus remote location	As in B.A.T.
Dispersion of unignited gases	Elevated flare	Elevated flare
Reliability:		
Flame stability	Elevated utility flare	Elevated utility flare
Ignition systems	Continuous pilot Flame front ignition	As in B.A.T.
No burn-back or flame pulldown	Elevated staged multi-point flare	Elevated special design utility flare with velocity seal
Other:		
Minimum space requirement	Elevated flare	Elevated flare

(1) Assumes smoking gases are flared.
(2) 25% of maximum emergency relief capacity.
(3) 75% of maximum emergency relief capacity.

9.0 REVIEW OF CURRENT REGULATORY PRACTICES

9.1 Province of Alberta

In the Province of Alberta regulations in accordance with:

- The Department of the Environment Act
- The Clean Air Act
- The Energy Resources Conservation Act
- The Oil and Gas Conservation Act

are the means by which regulatory requirements for flare stacks are transferred to industry.

In general the performance requirements of a flare system are stipulated in the regulations with but few details of design being specified.

The Energy Resources Conservation Board (ERCB) and the Department of Environment (ADOE) have the responsibility to administer the Acts.

Prior to the installation of a facility, a proponent must be able to show that a proposed flare system will perform as required.

9.1.1 Oil and Gas Conservation Regulations

The following are relevant items extracted from "The Oil and Gas Conservation Regulations"

Part 7.0 Production Operations
Air Pollution Control
- Referring to the operation of a plant or battery.

7.040 - No items shall be burned except
- o under conditions of controlled combustion where there is no significant or visible emission of smoke unless written approval is obtained.

9.1.1 Oil and Gas Conservation Regulations (cont'd)

7.060 - When handling gas with more than 10 moles per kilomole of hydrogen sulfide or as may be stipulated by the ERCB, flaring systems will
  (a) be at least 12 meters high or as may be stipulated in a particular case
  (b) be provided with a suitable wind guard
  (c) be provided with a continuous ignition device if the gas is intermittent

- Written approval required for flaring during any period of cleaning out the well or during well service operations.
- When liquids are produced they must be separated and all gas discharged to an approved stack.

Part 9.0 Processing Plants

9.040 - Operators of processing plants must maintain any air contaminants within concentrations as permitted in the Clean Air (maximum levels) Regulations under the Clean Air Act or as may be specified by the ERCB or the ADOE.

9.050 - When treating gas for hydrogen sulfide removal, and where sulfur compounds are emitted through a flare stack without prior incineration, measurements are required for the daily average volume of flare stack gases and the daily average concentration of hydrogen sulfide and of any other sulfur present in the flare stack gases.

- Emissions of the following shall be controlled to the satisfaction of the ERCB and the ADOE:
  - o Unburned hydrocarbon vapours
  - o Odorous materials
  - o Smoke
  - o Noise

9.1.1 Oil and Gas Conservation Regulations (cont'd)

Part 15.0 Certain Applications
Flaring of Sour Gas

15.240 - An application under section 7.060 for approval of the method, stack height and equipment used to flare gas containing more than 10 moles per kilomole hydrogen sulphide, shall include

(a) the dimensions of the proposed stack (height and diameter),
(b) a map showing the location of the well, topography of the area, limits of cities, towns or villages, residences and recreation areas within a three-kilometer radius of the well site,
(c) the maximum rate at which the well will be flowed,
(d) the total volume of gas to be flared,
(e) an analysis on a condensate-free basis of the gas from the well in question or if a gas sample from the well is not available, an analysis of the gas from the same pool,
(f) the anticipated rate of liquid production, and
(g) a description of the method of handling the liquid production from the well.

9.1.2 The Clean Air Act Regulation

These regulations stipulate

- the Maximum Permissible Concentration of Air Contaminants in the Ambient Air
- the Maximum Visible Emissions Which are Permitted
- the Maximum Concentrations of Particulates in an Effluent Stream to the Atmosphere
- the Maximum Amount of Vinyl Chloride in an Effluent Stream from a Vinyl Chloride Plant

9.1.2 The Clean Air Act Regulation (cont'd)

The regulations do not state any design details to which flares must conform.

The following are relevant items extracted from the Clean Air Act Regulations.

PART 1 Maximum Permissible Concentration of Air Contaminants in the Ambient Air

	Microgram/ Cubic Meter	Time Period
Sulphur Dioxide	30	Annual arithmetic means
	150	24 hrs.
	450	1 hr.
Hydrogen Sulphide	4	24 hrs.
	14	1 hr.
Nitrogen Dioxide	60	Annual arithmetic means
	200	24 hrs.
	400	1 hr.
Carbon Monoxide	Milligrams/ Cubic Meter	
	6	8 hrs.
	15	1 hr.
Oxidants as equivalent ozone	Micrograms/ Cubic Meter	
	50	24 hrs.
	160	1 hr.
Suspended particulates	60	Annual geometric means
	100	24 hrs.

PART 2 Visible Emissions

"10(1) The maximum visible emissions permitted to be emitted anywhere in Alberta from any stationary source of air pollution and any burning or other activity producing air contaminants shall not exceed an opacity of 40% averaged over a period of six consecutive minutes."

9.1.2 The Clean Air Act Regulation (cont'd)

Some minor exceptions are allowed.

"11(1) The opacity of visible emissions prescribed in section 10 shall only be determined by an observer.

(2) An observer shall determine the opacity of the visible emissions prescribed under section 10 by averaging twenty-four consecutive readings taken over a period of six consecutive minutes at fifteen second intervals."

PART 3 Particulate Emissions

Subject to certain exceptions shall not exceed

"2(a) 0.20 pounds per 1000 pounds of effluent adjusted to 50% excess air for products of combustion resulting from the combustion of solid and liquid fuels including coal, coke, hogged fuel, distillate and residual fuel oils, but excluding the incineration of refuse;

(b) 0.20 pounds per 1000 pounds of effluent resulting from"

(A number of manufacturing processes are listed including)

"(vi) the manufacturing of chemicals and allied products,
(vii) the manufacturing of commercial fertilizers,
(viii) the processing of hydrocarbons and petroleum products,"

Of the total particulates specified, not more than 50% of the maximum allowable concentration of particulates permitted shall be retained on a 325 mesh screen.

9.1.3 Guidelines for Design

The Regulatory Authorities use guidelines, based upon good practice, which they follow when reviewing applications for plants and associated flare systems prior to their granting of approval for an installation. The following are applied during their review.

9.1.3 Guidelines for Design (cont'd)

- "Guidelines for Plume Dispersion Calculations" (203) a publication by Alberta Environment, which contains prescribed methods for the design of flares as related to ground level concentrations of pollutants. This publication also prescribes a minimum heat value for sour gas going to flare of 9.0 MJ/m^3 (242 BTU/SCF) to ensure adequate combustion.
- The Flare Pilot Light should be relatively non-extinguishable or equipped with an automatic ignitor.
- The application of liquid knockout facilities is reviewed.
- All items relative to conformance with the regulations are reviewed.

The Regulatory Authorities continuously monitor the results of their efforts and adapt their guidelines as may be desirable to protect the interest of the public without imposing undue hardship on industry.

9.2 Summary of Practices

The following tables have been prepared summarizing the various regulatory practices which are contained in Appendix "A" and Part 9.1 heretofore.

Summary of Regulatory Practices	Table 9.1.1
	9.1.2
	9.2.1
	9.2.2
	9.3.1
	9.3.2
	9.4.1
	9.4.2

9.2 Summary of Practices (cont'd)

Some general observations may be made concerning the information in the tables. Generally all of the jurisdictions tabulated require smokeless operation of flares, commonly defined by a basic visible emission opacity limit of 20%, except for Illinois at 30% and Alberta at 40%. New continuous flares (not emergency) in all U.S. jurisdictions are required by EPA regulations to provide for a continuous flame and pilot flame monitoring. Most U.S. jurisdictions, as well as Alberta, apply these requirements to all flares.

Minimum heat contents of the flared gases, which are required throughout the U.S. for new continuous flares, and in Texas for all flares, are comparable to Alberta requirements. Maximum ground level sulfur dioxide concentration limitations are generally more stringent in Alberta than in the U.S. jurisdictions cited (Bay Area of California, Texas and Illinois).

Maximum allowable ground level concentrations of hydrogen sulfide appear to be lower in Alberta (0.01 ppm, 1 hr.) than in Texas (0.08/0.12 ppm, 1/2 hr.). Alberta requirements regarding particulates ground level concentrations (60 mmg/m^3, annual) appear to be somewhat more stringent than those of Illinois (60/75 mmg/m^3, annual). The same observation also applies to CO and NO_2. Only Alberta stipulates maximum ground level concentrations for oxidants, and only Texas stipulates a minimum destruction efficiency for flares.

Table 9.1.1

SUMMARY OF REGULATORY PRACTICES

	PARAMETER	EPA FEDERAL REG. 40-CFR 60 & 61 A	CALIFORNIA					TEXAS
			State Air Resources Board S A R B B	Bay Area A Q M D C	South Coast A Q M D D	Kern County K C A P C D E	Ventura F	G
1.	FEDERAL REGISTER 40 CFR 60 & 61	Col A	For New Flares. Continuous Flares, Not Emergency Flares		For New Flares Continuous Flares, Not Emergency Flares			
2.	CONTINUOUS FLAME	Must be present at all times that emissions are vented	Col A		Col A	Adequate provision for reliable ignition required		Windshields and good piloting required
3.	MONITOR OF PILOT FLAME	Must be monitored by thermocouple or other device	Col A		Col A			Detection and alarm and/or auto relight required
4.	SMOKELESS	Smokeless manner req'd Measured by Method 22	Col A Col A	Smokeless max. Ringlemann #1 or 20% opacity	Col A Col A	Adequate provisions for introduction of combustion air forced draft or natural draft required	Must not exceed Ringlemann #1 or 20% opacity	Steam or air assist for smokeless operation required
5.	VISIBLE EMISSIONS	Permitted for a max. of 5 min. in any 2 hr. period	Col A	Maximum of 3 min/hr in aggregate	Col A	Provision required for shielding if near residential areas		Acid gas flares before 1972 30% opacity avg.5 min. after 1972 20% opacity avg.5 min. all others; no visible emissions for more than 5 min. over 2 hrs.
6.	HEAT CONTENT of flared gas minimum	Steam and air assist 300 BTU/scft Non-assisted 200 BTU/scft	Col A		Col A			Minimum = 200-300 BTU/scft

SUMMARY OF REGULATORY PRACTICES

Table 9.1.2

		LOUISIANA	ALABAMA	ILLINOIS	MICHIGAN	KANSAS	ALASKA	ALBERTA
	PARAMETER	H	I	J	K	L	M	N
1.	FEDERAL REGISTER 40 CFR 60 & 61	Must meet Plus as listed below	For New Flares. For Flares in existence see (1) Exceptions below					
2.	CONTINUOUS FLAME	Continuous burning pilot light required	Col A		* Continuous burning pilot required. Automatically commence shut-in of facility one second after flame out of flare			Should be relatively non-extinguishable or
3.	MONITOR OF PILOT FLAME	Automatic alarm or re-ignition required	Col A		* Fail safe sensors req'd to monitor flame			Equipped with automatic ignitor
4.	SMOKELESS	Not darker than Ringlemann #1 more than aggregate of 6 hrs. in 10 consecutive days	(1) Measured by EPA Method #9	Defined as not darker than Ringlemann #1 (20% opacity)	Max. 6 min. average of 20% opacity except for one 6 min. average/hr of not more than 27% opacity	Smokeless type required, air or steam assist		Required
5.	VISIBLE EMISSIONS	Col A	(1) Not greater than opacity of 20% for 6 min. avg. except during one 6 min. period in any 60 min. period discharge is allowed up to 40% opacity	Max.opacity 30% except 30-60% aggreg. 8 min. in any 60 min. providing such source is more than 1000 ft. from one of same owner and that the more opaque emissions are limited to 3 times in any 24 hr. period		Less than 20% opacity req'd	Visible emiss. may not be greater than 20% for more than a total of 3 min. in any 1 hr. (20% opacity)	Shall not exceed an opacity of 40% avg. over a period of 6 consec. min.
6.	HEAT CONTENT of flared gas minimum	(2) Minimum based on equation using SO2 emissions as a variable	Col A					Guideline requires that should be not less than 9.0 MJ/m3 242 BTU/scft

SUMMARY OF REGULATORY PRACTICES

Table 9.2.1

			CALIFORNIA					
	PARAMETER	EPA FEDERAL REG. 40-CFR 60 & 61 A	State Air Resources Board S A R B B	Bay Area A Q M D C	South Coast A Q M D D	Kern County K C A P C D E	Ventura F	TEXAS G
7.	EXIT VELOCITIES	Steam & Non Assist a) less than 60 fps or	Col A		Col A	Properly Sized Flare stack required		Per 40-CFR-60.18
	V. max. calculated by prescribed method	b) less than 400 fps if heat content exceeds 1000 BTU/scf or	Col A		Col A			Col A
		c) less than V. max. if heat content between 300 & 1000 BTU/scft	Col A		Col A			Col A
		Air Assisted less than V.max based on heat content	Col A		Col A			Col A
8.	ODOROUS SUBSTANCES			- Dilution of sample specified for vent height - Not to be discharged				
9.	SO2 MAX. GROUND LEVEL CONCENTRATIONS			3 min. contin. - 0.5 ppm 60 min. avg. - 0.5 ppm 24 hr. avg. - 0.04 ppm		Adequate provision for control of sulfur compounds required		Galveston & Harris Counties 0.28 ppm 1/2 hr average Jefferson & Orange Counties 0.32 ppm 1/2 hr average Other Counties 0.4 ppm 1/2 hr average
10.	GENERAL EMISSIONS			Maximum in stack or vent dry @ 300 ppm				

SUMMARY OF REGULATORY PRACTICES

Table 9.2.2

	LOUISIANA	ALABAMA	ILLINOIS	MICHIGAN	KANSAS	ALASKA	ALBERTA
PARAMETER	H	I	J	K	L	M	N
7. EXIT VELOCITIES							
	Col A	Col A					
V. max. calculated by prescribed method	Col A	Col A					
	Col A	Col A					
	Col A	Col A					
8. ODOROUS SUBSTANCES							
9. SO2 MAX. GROUND LEVEL CONCENTRATIONS			Primary: Annual 0.03 ppm 24 hrs. 0.14 ppm not to be exceeded more than once per year Secondary: 3 hrs. 0.5 ppm not to be exceeded more than once per year				30 mmg/m3 Annual Arith. mean 150 mmg/m3 24 hr 450 mmg/m3 1 hr Prescribed method for calculating is issued
10. GENERAL EMISSIONS	Maximum instantaneous SO2 emission not greater than 800 lbs/hr for 50 ft.stack Must be less than 25 tons per year for 25 ft. stack		Max. emissions of SO2 from any source = 2000 ppm except Batch Process, or no sulfur recovery or SO2 not over 500#/hr or 3500#/8 hrs.				

SUMMARY OF REGULATORY PRACTICES

Table 9.3.1

PARAMETER	EPA FEDERAL REG. 40-CFR 60 & 61	CALIFORNIA					TEXAS
		State Air Resources Board C A R B	Bay Area A Q M D	South Coast A Q M D	Kern County K C A P C D	Ventura	
	A	B	C	D	E	F	G
11. DESTRUCTION EFFICIENCIES							98%
12. H2S MAX. GROUND LEVEL CONCENTRATIONS							Residential etc. areas, 0.08 ppm 1/2 hr. average. Other 0.12 ppm 1/2 hr average
13. CO EMISSIONS							
14. PARTICULATES MAXIMUM GLC							
15. OXIDANTS AS EQUIVALENT OZONE							
16. CO MAXIMUM GLC							
17. NO2 MAXIMUM GLC							

SUMMARY OF REGULATORY PRACTICES

Table 9.3.2

	LOUISIANA	ALABAMA	ILLINOIS	MICHIGAN	KANSAS	ALASKA	ALBERTA
PARAMETER	H	I	J	K	L	M	N
11. DESTRUCTION EFFICIENCIES							
12. H2S MAX. GROUND LEVEL CONCENTRATIONS	3) 0 lbs/hr @ 20 ft stack 4 lbs/hr @ 68 ft stack except may be up to 50 lbs/hr in 25 ft stack when heat release reqmts. are met			Mass flow of H2S to flare to be monitored on a periodic schedule			4 mmg/m3 24 hrs 14 mmg/m3 1 hr
13. CO EMISSIONS			Max. = 200 ppm Corrected to 50% excess air				
14. PARTICULATES MAXIMUM GLC			P - Primary S - Secondary P - 75 mmg/m3 annual 260 mmg/m3,24 hr not more than once per year S - 60 mmg/m3 annual 150 mmg/m3 24 hr not more than once per year				Suspended Particulates 60 mmg/m3 annual geometric mean 100 mmg/m3 24 hr Emissions with certain exceptions shall not exceed 0.2 lbs./1000 lbs. adjusted to 50% excess air.
15. OXIDANTS AS EQUIVALENT OZONE							50 mmg/m3 24 hr 160 mmg/m3 1 hr
16. CO MAXIMUM GLC			8 hrs 9 ppm not more than once per year 1 hr 35 ppm not more than once per year				6 mg/m3 8 hrs 15 mg/m3 1 hr
17. NO2 MAXIMUM GLC			Annual 0.05 ppm				60 mmg/m3 Annual Arithmetic Mean 200 mmg/m3,24 hrs 400 mmg/m3, 1 hr

SUMMARY OF REGULATORY PRACTICES

Table 9.4.1

		CALIFORNIA					
PARAMETER	EPA FEDERAL REG. 40-CFR 60 & 61 A	State Air Resources Board C A R B B	Bay Area A Q M D C	South Coast A Q M D D	Kern County K C A P C D E	Ventura F	TEXAS G
18. GENERAL REQUIREMENTS AND GUIDELINES		Local air pollution control districts regulate opacity & public nuisance		EPA Air Pollution Engineering Manual Chapter 10 Petroleum Equipment	Properly Sized Knockout Drum required	No Specific Design Requirements for Flares	

SUMMARY OF REGULATORY PRACTICES

Table 9.4.2

	LOUISIANA	ALABAMA	ILLINOIS	MICHIGAN	KANSAS	ALASKA	ALBERTA
PARAMETER	H	I	J	K	L	M	N
18. GENERAL REQUIREMENTS AND GUIDELINES	Must meet all EPA Reqm'ts. 1) Process Flare System C,H,O,Gas 25 ft min.height 2) Emergency Flare 50 ft min. height 3) Production tank battery processing sour liquid			* Sour Gas must be burned in smokeless flare, approved incinerator or other means with discharge elevated * Except if crude oil system producing less than 10 B/D Sour Gas more than one gr. H2S/100 scft or 10 gr. S/100 scft	Require flare operations obtain exemption (K.A.R. 28-19-45 open burning prohibited) for each flare operated No specific guidelines		Require installation to be approved by the ERCB and DE Flare stack must be at least 12 m for field installations which flare gas with more than 1% H2S

10.0 REFERENCES

10.1 General

Listed herein are the items which have been perused during the preparation of this report.

In addition there have been numerous personal communications with a majority of the vendors who are associated with Flare Systems.

The listings have been arbitrarily grouped as to their source i.e. report, article, paper, publication, code, etc.

10.2 Regulations, Codes and Guidelines

201 "Guide for Pressure Relieving and Depressuring Systems"
API Recommended Practice 521
Second Edition September 1982
American Petroleum Institute

202 "Manual on Disposal of Refinery Wastes: Volume on Atmospheric Emissions"
API Publication 931
September 1975
American Petroleum Institute

203 "Guidelines for Plume Dispersion Calculations"
Environment Protection Services
May 1980
Alberta Environment

Government of the Province of Alberta (204 through 207)
204 "Clean Air (maximum levels) Regulation", 1984
205 "The Energy Resources Conservation Act and Regulations"
206 "The Oil and Gas Conservation Act and Regulations"
207 "Energy Resources Conservation Board Informational Letters"

10.2 Regulations, Codes and Guidelines (cont'd)

208 Federal Register
40CFR Parts 60 & 61
[AD-FRL-2913-7]
January 1986

209 "Air Pollution Engineering Manual: Second Edition"
EPA AP-40
U.S. Environmental Protection Agency
1973

10.3 Reports

301 "A Preliminary Study of the Chemical Composition and Combustion Efficiency of a Sour Gas Flare"
RMD Report 85/30 - 1985
Alberta Environment
Western Research Division of Bow Valley, Resources Ltd., Leahy, Paskall, Schroeder, Zelensky.

302 "Twin Butte Soils and Water Evaluation Task Force: Executive Summary"
August 1984
Alberta Environment
Ashworth, Carpenter, Clark, Dabrowski, Pharis, Tollefson, Zukiwsky

303 "Twin Butte Soils and Water Evaluation Task Force: Technical Report"
August 1984
Alberta Environment
Ashworth, Carpenter, Clark, Dabrowski, Pharis, Tollefson, Zukiwsky

10.3 Reports (cont'd)

United States Environmental Protection Agency (304 through 309)
Project Summary
304 "Flare Efficiency Study"
McDaniel
EPA 600/S2-83-052 - January 1984

Project Summary
305 "Evaluation of the Efficiency of Industrial Flares Background, Experimental Design, Facility"
Joseph, Lee, McKinnon, Payne, Pohl
EPA 600/S2-83-070 - January 1984

Project Summary
306 "Evaluation of the Efficiency of Industrial Flares - Test Results"
Pohl, Payne, Lee
EPA 600/S2-84-095 - July 1984

Project Summary
307 "Flare Efficiency Monitoring by Remote Infra Red Sensing: A Feasibility Demonstration"
Persky and Spellicy
EPA 600/S7-84-053 - May 1984

Project Summary
308 "Evaluation of the Efficiency of Industrial Flares: Flare Head Design and Gas Composition"
Pohl, Soelberg
EPA 600/S2-85-106 - January 1986

EPA Research and Development
309 "Evaluation of the Efficiency of Industrial Flares: H_2S Gas Mixtures and Pilot Assisted Flares"
Pohl & Soelberg
EPA 600/2-86-080 - September 1986

10.3 Reports (cont'd)

310 "Investigation Into the Feasibility of Continuously Monitoring Refinery Flares"
California Air Resources Board
CH2M HILL Inc.
December 1985

311 Not Published to Date
"A Review of Flaring in the Sour Gas Industry With Particular Reference to the Emission of Pollutants"
March 1985
Environment Canada
Karim, Rowe, Tollefson
University of Calgary

10.4 Papers and Articles

401 "Mixing and Chemical Reactions in Industrial Flares and Their Models"
Physico Chemical Hydrodynamics Vol.-1 pp. 27-40 - 1980
University of Waterloo
T. A. Brzustowski

402 "Odour Control for Sour Gas Dehydrators"
June 1986
Western Research, Division of Bow Valley Resources Services
Colley, Rutberg, Smolarski
and
University of Calgary
W. Y. Svrcek

10.4 Papers and Articles (cont'd)

403 "Flaring vs Thermal Incineration of Waste Gases in the Oil and Gas Industry"
November 1982
Western Research, Division of Bow Valley Resource Services Ltd.
Colley, Berlie, Zelensky

404 "U.S. EPA's Flare Policy"
Update and Review
Chemical Engineering Progress - April 1985
B. C. Davis

405 "Estimate Flare Radiation Intensity"
Hydrocarbon Processing - May 1985
DeFaveri, Ferranto, Fumarola, Zonato

406 "Flaring Combustion Efficiency - A Review of the State of Current Knowledge"
Proceedings of the Annual Meeting of the A.P.C.A. - June 1983
Dubnowski, Davis

407 "Flare System Operating Costs Can Be Reduced"
Oil & Gas Journal - September 23, 1985
R. A. Corbett

408 "Predict Flare Noise"
Hydrocarbon Processing - April 1986
N. D. Narasimhan

409 "How to Compute Safe Purge Rates"
Hydrocarbon Processing - May 1964
H. W. Husa

10.4 Papers and Articles (cont'd)

410 "Unique Flare System Retards Smoke"
Hydrocarbon Processing - January 1972
W. Lauderback

411 "Practical Design of Flare Stacks"
Hydrocarbon Processing - May 1968
G. R. Kent

412 "Find Radiation Effect of Flares"
Hydrocarbon Processing - June 1968
G. R. Kent

413 "Smokeless Flares"
Hydrocarbon Processing - October 1974
L. G. Vanderlinde

10.5 Publications

10.5.1 Publications by McGill Incorporated

501 "Low Pressure Flare Processing for Energy Conservation"
May 1984
American Institute of Chemical Engineers
K. J. Herbert
(also Energy Progress - June 1985)

502 "Energy Conservation in Flare Purging Systems"
May 1985
K. J. Herbert & R. Rawlings
American Petroleum Institute
Order No. 820-00026

10.5.1 Publications by McGill Incorporated (cont'd)

503 "Flare Equipment Description and Calculation Procedures"
December 1981
K. J. Herbert

504 "Air Assisted Flare Systems for Production Facilities"
November 1980
K. J. Herbert

505 "Acid Gas Disposal Comparison of Flaring and Thermal Combustion"
June 1981
K. J. Herbert

10.5.2 Publications by National Air Oil Burner Company

506 "Flares Design and Operation"
1983
J. F. Straitz III

507 "Flaring for Gaseous Control in the Petroleum Industry"
June 1978
J. F. Straitz III

508 "Solving Flare-Noise Problems"
May 1978
J. F. Straitz III

509 "Offshore Flares: Engineering & Safety"
November 1978
J. F. Straitz III

10.5.2 Publications by National Air Oil Burner Company (cont'd)

510 "Proper Flare Operation Conserves Energy in Refinery"
Oil & Gas Journal - January 1, 1979
J. F. Straitz III

511 "Flaring of Gas for Safety and Environmental Protection"
Offshore Engineer - December 1977
J. F. Straitz III

512 "Flare Design for Pollution Control"
C. N. Knook

513 "Smokeless Flaring at High Rates"
J. F. Straitz III

514 "Vapour Incineration"
J. F. Straitz III

515 "Noise Control for a Flare Near a Community"
R. D. Bruce

516 "Make the Flare Protect the Environment"
Hydrocarbon Processing - October 1977
J. F. Straitz III

10.5.3 Publications by John Zink Company

517 "RACT for VOC - A Burning Issue"
Pollution Engineering Magazine - July 1983
M. Keller & R. Noble

518 "Designing Flares for Enhanced Service Life"
June 1983
M. Keller & S. Smith

519 "Environmental Factors Versus Flare Applications"
1978
R. Schwartz & M. Keller

520 "Advances in Offshore Flaring Technology"
1983
R. Schwartz & H. Glomm

521 "Flaring in Hostile Environments"
1983
R. Schwartz & M. Keller

522 "Total System Approach to Flare System Design"
October 1983
S. Smith & T. Cawte

523 "Flares - Safe, Effective, Disposal at an Affordable Cost"
1984
R. Schwartz, M. Keller & R. Noble

APPENDIX "A"

SUMMARY OF CURRENT FLARING REGULATORY REQUIREMENTS IN VARIOUS U.S. JURISDICTIONS

CALIFORNIA

STATE AIR RESOURCES BOARD:

- New flares subject to EPA New Source Performance Standard (NSPS) (40 CFR, Parts 60 and 61) for continuous, not emergency flares.

- local air pollution control districts (APCD's) have regulations concerning opacity and creation of a public nuisance.

- California Air Resources Board (CARB) staff recommend that CARB (June 19/86) determine that devices which monitor on/off status of refinery flares are technologically feasible, available and economically reasonable. Staff further recommended that the CARB:
  (1) Encourage local APCD's to adopt rules requiring refiners to install on/off monitors.
  (2) Direct that staff work with industry and the APCD's to develop workable but standardized definitions of "on" and "off".
  (3) Encourage APCD's to request grab sample composition analyses of flare feed stream gases.
  (4) Direct the staff to follow these developments and based on analysis of data from on/off monitors and grab samples, staff may recommend that the California Air Pollution Control Officers Association Technical Review Group (TRG) consider need to develop a suggested control measure (SCM) for refinery flares.

BAY AREA - Air Quality Management District (AQMD)

Standards

Ringelmann No. 1 Limitation:

Except as provided in Sections 6-303 and 6-304, a person shall not emit from any source for a period or periods aggregating more than three minutes in an hour, a visible emission which is as dark or darker than No. 1 on the Ringelmann Chart, or of such opacity as to obscure an observer's view to an equivalent or greater degree.

Opacity Limitation:

Except as provided in Sections 6-303 and 6-304, a person shall not emit from any source for a period or periods aggregating more than three minutes in any hour an emission equal to or greater than 20% opacity as perceived by an opacity sensing device, where such device is required by District regulations.

TABLE 1

DILUTION RATES

Elevation of Emission Point above Grade in Meters (Feet)	Dilution Rate (Volumes of odor-free air per volume of source sample)
Less than 9 (30)	1,000
9 to 18 (30 to 60)	3,000
18 to 30 (60 to 100)	9,000
30 to 55 (100 to 180)	30,000
greater than 55 (180)	50,000

Standards

General Limit on Odorous Substances:

A person shall not discharge any odorous substance which remains odorous after dilution with odor-free air as specified in Table 1. Samples shall be collected and analyzed as prescribed in Section 7-400.

Limit on Odorous Substances at or Beyond Property Line:

A person shall not discharge any odorous substance which causes the ambient air at or beyond the property line of such person to be odorous and to remain odorous after dilution with four parts of odor-free air.

$\underline{SO_2}$: (flares not specifically addressed)

Maximum Ground Level Concentrations (GLC's):

0.5 ppm continuously for three consecutive minutes

0.5 ppm averaged over 60 consecutive minutes

0.04 ppm averaged over 24 hours

General Emission Limitation (Maximum GLC's not applicable):

300 ppm (dry) in stack or vent.

SOUTH COAST - Air Quality Management District

Flare stacks are basically in continuous flaring or intermittent/emergency flaring service. The Environmental Protection Agency (EPA) has a present flare policy/regulation i.e. the New Source Performance Standards (NSPS) covering all equipment which is new or modified under such a definition. This policy was developed by its office of Air Quality Planning and Standards. The NSPS only apply to flares in continuous flaring service. The first promulgated standards are referenced under EPA CFR (Code of Federal Regulations), Title 40, Part 60, Subpart VV. As new R & D information becomes available to EPA, the regulation will be modified and expanded to other industries/equipment under control considerations. Currently, this referenced standard applies only to SOCMI (Synthetic Organic Chemicals Manufacturing Industry).

SCAQMD uses EPA AP-40 publication "Air Pollution Engineering Manual" pp. 581 - 626 for design, operation and monitoring considerations of flare stacks.

KERN COUNTY - Air Pollution Control District

Based upon design analysis and field observation, KCAPCD developed the following list of requirements for flare stacks. Flares utilizing these provisions are capable of being operated in compliance with KCAPCD requirements.

(1) Properly sized gas/liquid separator preceding the flare stack.

(2) Adequate provisions for the control of sulfur compounds, e.g. a caustic scrubber for H_2S removal.

(3) Properly sized flare stack.

(4) Adequate provisions for the introduction of combustion air. (Forced draft blower for heavier hydrocarbons and natural draft system for lighter hydrocarbons.)

(5) Adequate provisions for reliable ignition of flared gases.

(6) Provisions for flame shielding if flare is to be located near residential areas.

COUNTY OF VENTURA - Air Pollution Control District

- No specific design requirements for flares
- Operating requirements: must not exceed Ringelmann No. 1 or 20% opacity.

TEXAS

For new sources (after September 1, 1971) generally request:

- 98% destruction efficiency
- minimum BTU content waste gas 200 - 300 BTU/SCF
- maximum tip velocities as per New Source Performance Standard (NSPS) (40 CFR 60.18).
- windshields and good piloting/ignition rings to ensure stable flame, even in high winds
- steam or air assist for smokeless operation
- continuous pilot with thermocouple detector and alarm for flameout, or automatic relight system, or automatic ignition system to ensure reliable destruction of waste gas.

Specific Rules:

Built: Acid Gas Flares:

Before '72 - not to exceed opacity of 30% average over 5 minute period

After '72 - not to exceed opacity of 20% average over 5 minute period

All Other Gas Flares:

- No visible emissions for more than 5 minutes in any two hour period.

Maximum SO_2 GLC:

Galveston and Harris Counties	- 0.28 ppm averaged over 1/2 hour period
Jefferson & Orange Counties	- 0.32 ppm averaged over 1/2 hour period
Other Counties	- 0.40 ppm averaged over 1/2 hour period

Maximum H_2S GLC:

Affecting residential, recreational, business or commercial property:

0.08 ppm averaged over 1/2 hour period.

Affecting other property:

0.12 ppm averaged over 1/2 hour period.

LOUISIANA

Not darker than No. 1 on the Ringelmann Smoke Chart more than an aggregate time of six hours in any ten consecutive days. If emergency cannot be controlled in six hours, Commission to be notified as soon as possible - exemption not automatic.

Exemption may be granted during startup and shutdown if flaring not due to poor maintenance, etc. Detailed report required.

In addition the following are exempt from the permit and control requirements of the Louisiana Air Quality Control regulations because they are deemed to be "insignificant sources" (must meet all Federal EPA regulations):

- Any elevated, vertical, smokeless process flare system provided that:
  (a) There shall be no visible emissions from the flare for more than six hours in a ten day period except as provided above.
  (b) The flare is equipped with a continuously burning pilot light plus either an automatic re-ignition system or automatic alarm or other system that provides immediate notification of appropriate supervisory personnel that the flare pilot has gone out.
  (c) The flare burns waste gases containing except for trace amounts only carbon, hydrogen, oxygen or compounds derived from these elements.
  (d) The height of the flare is at least 25 feet.

- Any elevated vertical smokeless flare system designed to be used only as an emergency relief system provided that:
  - (a) There shall be no visible emissions from the flare for more than six hours in ten days as provided by above.
  - (b) The flare is equipped with a continuously burning pilot light plus either an automatic re-ignition system or an automatic alarm or other system that provides immediate notification of appropriate supervisory personnel that the flare pilot has gone out.
  - (c) The flare height is at least 50 feet.
  - (d) The flare burns vent gases containing only carbon, hydrogen, nitrogen, oxygen, sulfur or compounds derived from these elements.
  - (e) The maximum instantaneous emission of sulfur dioxide will be no more than 800 pounds per hour.
  - (f) There is normally no flow of process waste to the flare. The flare is used only during an emergency.
  - (g) The heat release of the flare shall be greater than or equal to the following values for flares emitting sulfur dioxide containing compounds:

$$Q = 0.129 \times 10^5 \frac{\text{BTU/hr}}{\text{lb/hr}} \times E_{SO_2}$$

Where: Q = Minimum required heat release, BTU/hr
E_{SO_2} = SO_2 emission, lb/hr

- Any new or modified production tank battery processing sour crude oil and condensate provided that:
  - (a) All requirements of Standard Exemption No. 16 for batteries handling sweet crude oil and condensate are satisfied.
  - (b) Total emission rate of hydrogen sulfide from operation of the battery (including upsets) does not exceed 4 pounds per hour.
  - (c) H_2S emission vs stack height: minimum = 20 feet 4 lb/hr = 68 feet
  - (d) As an alternative to the requirements of (c), vents containing up to 50 lbs per hour of hydrogen sulfide may be burned in a smokeless flare that is equipped with a continuous pilot provided that the flare is at least 25 feet tall and meets the above requirements on heat release. The total emissions of sulfur dioxide from normal operations must be less than 25 tons per year.

ALABAMA

DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Regulations for Flare Stacks:
Effective January 21, 1986, EPA promulgated requirements for flares used to comply with standards under Title 40 of the Code of Federal Regulations, Part 60 (New Source Performance Standards) and Part 61 (National Emission Standards for Hazardous Air Pollutants). A copy of the final rule is enclosed. Any facility in this state that is affected by either NSPS or NESHAPS and chooses a flare as their control device must construct a flare meeting certain requirements which include the following:

(1) A flame must be present at all times that emissions are being vented to the flare.
(2) The presence of a pilot flame is to be monitored using a thermocouple or other device.
(3) The flare must be operated in a smokeless manner to be verified by EPA Reference Method 22, a visible emissions observation test.
(4) Minimum heat content of the gas being combusted and exit velocity limitations are also finalized and depend on the type of flare, i.e. steam assisted, air assisted, or non assisted.

Flares already in existence in this State (which are not used to comply with the aforementioned standards) are required to comply with State regulations concerning visible emission restrictions for stationary sources. Using EPA Reference Method 9 for a visible emissions observation test, the source cannot discharge any air contaminant of any equivalent opacity greater than 20% opacity, as determined by a six minute average. During one six minute period in any 60 minute period, the source is allowed to discharge any air contaminant of any equivalent opacity not greater than 40% opacity.

ILLINOIS

Definition: "Smokeless Flare" - not darker than No. 1 of the Ringelmann Chart (20% opacity).

Visual Emissions:

- Maximum opacity 30%, except 30 to 60% opacity for period or periods aggregating 8 minutes in any 60 minute period provided that such more opaque emissions occur from only one such emission located within 1,000 feet of any other such emission source of same owner or operator, and provided further that such more opaque emissions are limited to 3 times in any 24 hour period.

SO_2 Emissions:

- Maximum emission from any process emission source = 2,000 ppm. This does not apply to existing H_2S flares at chemical manufacturing plants, provided:
  (1) Said flares are operative on an existing batch type process, and
  (2) The H_2S being flared is not passed through a sulfur recovery unit, and
  (3) Emission of SO_2 from said flares does not exceed 500 lbs/hr and 3,500 pounds per 8 hour period, and
  (4) Provided, however, that if emission controls for said flares become economically reasonable and technically feasible, they shall be installed.

CO Emissions:

- Maximum emission from any process emission source = 200 ppm corrected to 50% excess air.

Maximum GLC's

Particulates:

- Primary (public health)
  Annual 75 ug/m^3
  24 hours 260 ug/m^3 not to be exceeded more than once per year.

- Secondary (public welfare)

  Annual 60 ug/m^3

  24 hours 150 ug/m^3 not to be exceeded more than once per year.

SO_2:

- Primary

  Annual 0.03 ppm

  24 hours 0.14 ppm not to be exceeded more than once per year.

- Secondary

  3 hours 0.5 ppm not to be exceeded more than once per year.

CO:

8 hours 9 ppm not to be exceeded more than once per year.

1 hour 35 ppm not to be exceeded more than once per year.

NO_2:

Annual 0.05 ppm

MICHIGAN

Sour gas that is burned at an oil or gas production facility must be burned in a smokeless flare, an approved incinerator, or other combustion system with elevated discharge to the atmosphere.

Flare, etc. must be equipped with continuously burning pilot flame and fail-safe sensors to detect flame extinguishment.

Exceptions to the above if facility is a crude oil battery producing less than 10 BPD per well.

Mass flow rate of H_2S going to flare must be monitored on a periodic schedule.

Automatic commence shut-in of the facility within one second after flameout of the flare.

The above requirements may be extended to flares handling sweet gas when the Air Quality Division (Department of Natural Resources) deems it necessary.

"Sour gas" = greater than one gr. H_2S/100 SCF or
greater than 10 gr. total S/100 SCF

Maximum six minute average of 20% opacity, except for one six minute average per hour of not more than 27% opacity.

KANSAS

DEPARTMENT OF HEALTH AND ENVIRONMENT

- Kansas has no specific guidelines for design of flares. They do require that they be "smokeless" (air or steam injected) type and visible emissions be less than 20% opacity.

- They also require flare operations to obtain an exemption from K.A.R. 28-19-45 Open Burning Prohibited for each flare operated.

ALASKA

- "Visible emissions may not reduce visibility through the exhaust effluent greater than 20% for a total of more than three minutes in any one hour". (20% opacity) no nonattainment areas within 100 km of Cape Romain. For further details, consult the July 12, 1985, Federal Register (50 FR 28544).

South Carolina Regulation No 62.5, Standard No. 7, Section IV, Part H was amended to describe the procedures to be followed when a new source in an attainment area (and subject to PSD review) would impair the visibility of a Class I area. The procedures require the State to provide the Federal Land Manager with the new source's permit application and an analysis of potential visibility impacts. The State must also consider any analysis concerning visibility impairment submitted by the FLM. If there is any disagreement with the FLM's comments, the State must explain its decision in writing and make that explanation available for public examination.

Regulation No. 62.5, Standard No. 7 Section IV, Part E, was amended to allow the State to require a source to perform visibility monitoring. Together, these two rule changes constitute an acceptable visibility new source review program.

Further details pertaining to these regulation changes are contained in the technical support document, which is available for public inspection at EPA's Regional Office in Atlanta, Georgia.

EPA is publishing this action without prior proposal because the Agency views this noncontroversial amendment and anticipates no adverse comments. This action will be effective 60 days from the date of this Federal Register unless, within 30 days of its publication, notice is received that adverse or critical comments will be submitted.

If such notice is received, this action will be withdrawn before the effective date by publishing two subsequent notices. One notice will withdraw the final action and another will begin a new rulemaking by announcing a proposal of the action and establishing a comment period. If no such comments are received, the public is advised that this action will be effective March 24, 1986.

Final Action: After reviewing South Carolina's visibility regulation revisions, EPA has found them to meet the requirements contained in 40 CFR 51.307(a); EPA is therefore approving the rule changes submitted by the State of South Carolina on June 3, 1985, as well as the State's visibility SIP narrative.

Under 5 U.S.C. 605(b), I certify that this SIP revision will not have a significant economic impact on a substantial number of small entities. (See 46 FR 8709).

The Office of Management and Budget has exempted this rule from the requirements of section 3 of Executive Order 12291.

Under section 307(b)(1) of the Act, petitions for judicial review of this action must be filed in the United States Court of Appeals for the appropriate circuit by March 24, 1986. This action may not be challenged later in proceedings to enforce its requirements (See 307(b)(2).).

List of Subjects in 40 CFR Part 52

Air pollution control, Incorporation by reference, Intergovernmental relation, Nitrogen dioxide, Ozone, Particulate matter, Sulfur oxides.

Note.—Incorporation by reference of the State Implementation Plan for the State of South Carolina was approved by the Director of the Federal Register on July 1, 1982.

Dated: January 9, 1985.

Lee M. Thomas,

Administrator.

Part 52 of Chapter I, Title 40.

40 CFR Part 52 is amended as follows:

PART 52—[AMENDED]

Subpart PP—South Carolina

1. The authority citation for Part 52 continues to read as follows:

Authority: 42 U.S.C. 7401–7642.

2. Section 52.2120 is amended by adding paragraph (c)(25) as follows:

§ 52.2120 Identification of plan.

* * * * *

(c) * * *

(25) Visibility new source review regulations and narrative visibility SIP were submitted to EPA on June 3, 1985.

(i) Incorporation by reference.

(A) Letter of June 3, 1985, from the South Carolina Department of Health and Environmental Control, and amendments to Regulation No. 62.5, Standard No. 7, Section IV, Part H; Regulation No. 62.5, Standard No. 7, Section IV, Part E; and Regulation No. 62.5, Standard No. 7, Section I, Part CC, adopted by the South Carolina Board of Health and Environmental Control on May 21, 1985.

(ii) Additional material.

(A) Narrative section, titled "Visibility Protection Control Strategy", adopted by the South Carolina Board of Health and Environmental Control on May 21, 1985.

* * * * *

[FR Doc. 86–972 Filed 1–17–86; 8:45 am]

BILLING CODE 6560–50–M

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40 CFR Parts 60 and 61

[AD–FRL–2913–7]

Equipment Leaks From Synthetic Organic Chemical Manufacturing Industry; Natural Gas Processing Plants; Equipment Leaks of Benzene Flare Requirements

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: On April 16, 1985 (50 FR 14941), EPA proposed an addition to the General Provisions of 40 CFR Part 60 containing requirements for flares used to comply with standards in 40 CFR Parts 60 and 61. This action promulgates the addition of flare requirements to the General Provisions. This action also promulgates the referencing of these requirements in standards of performance for equipment leaks from the synthetic organic chemical industry (SOCMI) and natural gas processing plants and in national emissions standards for equipment leaks of benzene.

DATES: These amendments and the incorporation-by-reference approved by the Director of the Federal Register are effective January 21, 1986.

Under section 307(b)(1) of the Clean Air Act, judicial review of the actions taken by this notice is available *only* by the filing of a petition for review in the U.S. Court of Appeals for the District of Columbia Circuit within 60 days of today's publication of this rule. Under section 307(b)(2) of the Clean Air Act, the requirements that are the subject of today's notice may not be challenged later in civil or criminal proceedings brought by EPA to enforce these requirements.

ADDRESSES: *Docket.* The docket, No. A–79–32, containing information considered by EPA in development of the promulgated standards, is available for public inspection between 8:00 a.m. and 4:00 p.m., Monday through Friday, at EPA's Central Docket Section (LE-131), West Tower Lobby, Gallery 1, 401 M Street SW., Washington, DC 20460. A reasonable fee may be charged for copying.

FOR FURTHER INFORMATION CONTACT: Mr. Fred Dimmick or Mr. Gil Wood, Standards Development Branch [telephone number (919) 541–5578] concerning policy and regulatory matters and Mr. Leslie B. Evans or Mr. Robert Rosensteel, Chemicals and Petroleum Branch [telephone number (919) 541–5671] concerning technology information; Emission Standards and

Engineering Division; U.S. Environmental Protection Agency; Research Triangle Park, North Carolina 27711.

SUPPLEMENTARY INFORMATION:

I. Background

The EPA promulgated final standards of performance for equipment leaks in SOCMI as Subpart VV of 40 CFR Part 60 on October 18, 1983 (48 FR 48328). On December 15, 1983, the Chemical Manufacturers Association (CMA) submitted to EPA a petition to reconsider the exit velocity limitations on flares used as control devices to comply with Subpart VV of 40 CFR Part 60. The EPA convened a proceeding to reconsider the exit velocity limitations on flares, based on the availability of new information of central relevance to the exit velocity limitation. After review of the new information in a study (Docket No. VII–B–1) completed by EPA's Office of Research and Development, EPA determined that the exit velocity limitation should be revised. The EPA also determined that the revised exit velocity limitation for flares should apply to several other standards in Parts 60 and 61. Therefore, on April 16, 1985 (50 FR 14941), EPA proposed changes in the exit velocity limitation for flares used as control devices to comply with Subparts VV, NNN and Kb of 40 CFR Part 60 and Subparts L and V of Part 61. The EPA also proposed to place the flare requirements in the General Provisions of Part 60 for easy reference by all subparts in Part 60 and Part 61.

The public comment period was from April 16, 1985 to June 17, 1985. The EPA received four comments on the proposed action and, after review of these comments, has no reason to change the proposal. This action finalizes the addition of the flare requirements to the General Provisions of 40 CFR Part 60 and references those requirements in the final standards of performance for equipment leaks in SOCMI (Subpart VV of Part 60) and in the final national emission standards for benzene equipment leaks (Subpart V of Part 61). The proposed changes to flare requirements in Subparts NNN and Kb of Part 60 and Subpart L of Part 61 will be finalized when action is taken to finalize those subparts. On June 24, 1985 (50 FR 26122), EPA promulgated flare requirements for natural gas processing plants in Subpart KKK of Part 60 identical to those promulgated today in the General Provisions of Part 60; this notice revises Subpart KKK to reference the flare requirements in the General Provisions.

II. The Standards

The final requirements for flares used to comply with standards of performance and national emission standards include some basic requirements: a flame must be present at all times that emissions are being vented to the flare and the flare must be operated in a smokeless manner. The presence of a pilot flame is to be monitored using a thermocouple or other device. Smokeless operation is to be verified by measuring visible emissions using Reference Method 22. Allowances are made for the occurrence of visible emissions for a maximum of 5 minutes during any 2-hour period. In addition to these basic requirements, the final requirements include minimum heat content and exit velocity limitations. Steam-assisted and air-assisted flares must combust gases with greater than 300 Btu per standard cubic foot (Btu/scf). Steam-assisted and nonassisted flares must be designed and operated with an exit velocity either (a) less than 60 feet per second (fps), (b) less than 400 fps if the heat content of gas being combusted is greater than 1,000 Btu/scf or (c) less than a velocity determined by an equation based on the heat content if the gas being combusted is between 300 Btu/scf and 1,000 Btu/scf. Air-assisted flares must be designed and operated with an exit velocity less than a velocity determined by another equation based on the heat content of the gas being combusted in the flare.

III. Environmental, Cost, Economic and Energy Impacts

There are no adverse environmental, economic or energy impacts associated with the promulgated flare requirements. However, the effect of the revision to the flare requirements would be to allow more existing flares to be used as control devices for complying with standards in Parts 60 and 61. To the extent that more existing flares can be used to comply with the standards, cost and economic impacts would be decreased.

IV. Public Participation

The revised flare requirements were proposed and published in the Federal Register on April 16, 1985 (50 FR 14941). Public comments were solicited at the time of proposal. The public comment period was from April 16, 1985 to June 17, 1985. The EPA also offered to hold a public hearing at the request of interested parties. No request for a public hearing was received, nor were any significant adverse comments received on the proposed action. The EPA's detailed response to the four comments is contained in the rulemaking docket.

V. Administrative

The docket is an organized and complete file of all the information considered by EPA in the development of this rulemaking. The docket is a dynamic file, since material is added throughout the rulemaking development. The docketing system is intended to allow members of the public and industries involved to readily identify and locate documents, so that they can effectively participate in the rulemaking process. Along with the statement of basis and purpose of the proposed and promulgated standards and EPA responses to significant comments, the contents of the docket, except for interagency review materials, will serve as the record in case of judicial review [section 307(d)(7)(A)].

The effective date of the new flare requirements depends on which Subpart is referencing the requirement. In general, however, section 111 of the Clean Air Act provides that standards of performance or revisions thereof become effective upon promulgation and apply to affected facilities of which the construction or modification was commenced after the date of proposal. Section 112 of the Clean Air Act also provides that emissions standards become effective upon promulgation and apply to all sources (whether new or existing) covered by the standard. In accordance with section 117 of the Act, publication of these promulgated standards was preceded by consultation with appropriate advisory committees, independent experts, and Federal departments and agencies.

The information collection requirements associated with the final flare requirements have been approved by the Office of Management and Budget (OMB) under the Paperwork Reduction Act of 1980, 44 U.S.C. 3501 *et seq.* However, burden estimates have not been made for this action. Instead, burden estimates are made for each of the standards to which flare provisions apply. The revision to the exit velocity had no impact on the recordkeeping and reporting requirements associated with Subpart VV of Part 60 or Subpart KKK [OMB Control Nos. (2060–0012 and 2060–0120)] or Subpart V of Part 61 [OMB Control No. (2060–0068)].

Under Executive Order 12291, EPA is required to judge whether a regulation is a "major rule" and, therefore, subject to certain requirements of the Order. The Administrator has determined that this regulation would result in none of the adverse economic impacts set forth in section 1 of the Order as grounds for finding a regulation to be a "major rule." This proposal makes complying with the existing standards less expensive, and thus would serve to decrease the economic impact. The Administrator has concluded that this rule is not "major" under any of the criteria established in the Executive Order.

This regulation was submitted to the OMB for review as required by Executive Order 12291. Any written comments from OMB to EPA and any EPA responses to those comments are available for public inspection, in Docket No. A–79–32, Central Docket Section, at the address given in the ADDRESSES section of this preamble.

The Administrator certifies that a regulatory flexibility analysis under 5 U.S.C. 601 et seq., is not required for this rulemaking because the rulemaking would not have significant impact on a substantial number of small entities. This proposal has no significant cost impact.

List of Subjects in 40 CFR Parts 60 and 61

Air pollution control, Reporting and recordkeeping requirements, Incorporation by reference, Intergovernmental relations, Synthetic organic chemical manufacturing industry, Sources of benzene emissions, Natural gas processing plants.

Dated: January 12, 1986.

Lee M. Thomas,

Administrator.

40 CFR Part 60 and Part 61 is amended as follows:

PART 60—[AMENDED]

1. The authority citation for Part 60 continues to read as follows:

Authority: Secs. 101, 111, 114, 116, 301, Clean Air Act as amended (42 U.S.C. 7401, 7411, 7414, 7416, 7601).

2. By adding § 60.18 to Part 60 Subpart A as follows:

§ 60.18 General control device requirements.

(a) *Introduction.* This section contains requirements for control devices used to comply with applicable subparts of Part 60 and Part 61. The requirements are placed here for administrative convenience and only apply to facilities covered by subparts referring to this section.

(b) *Flares.* Paragraphs (c) through (f) apply to flares.

(c)(1) Flares shall be designed for and operated with no visible emissions as determined by the methods specified in paragraph (f), except for periods not to exceed a total of 5 minutes during any 2 consecutive hours.

(2) Flares shall be operated with a flame present at all times, as determined by the methods specified in paragraph (f).

(3) Flares shall be used only with the net heating value of the gas being combusted being 11.2 MJ/scm (300 Btu/scf) or greater if the flare is steam-assisted or air-assisted; or with the net heating value of the gas being combusted being 7.45 MJ/scm (200 Btu/scf) or greater if the flare is nonassisted. The net heating value of the gas being combusted shall be determined by the methods specified in paragraph (f).

(4) (i) Steam-assisted and nonassisted flares shall be designed for and operated with an exit velocity, as determined by the methods specified in paragraph (f)(4), less than 18.3 m/sec (60 ft/sec), except as provided in paragraph (b)(4) (ii) and (iii).

(ii) Steam-assisted and nonassisted flares designed for and operated with an exit velocity, as determined by the methods specified in paragraph (f)(4), equal to or greater than 18.3 m/sec (60 ft/sec) but less than 122 m/sec (400 ft/sec) are allowed if the net heating value of the gas being combusted is greater than 37.3 MJ/scm (1,000 Btu/scf).

(iii) Steam-assisted and nonassisted flares designed for and operated with an exit velocity, as determined by the methods specified in paragraph (f)(4), less than the velocity, V_{max}, as determined by the method specified in paragraph (f)(5), and less than 122 m/sec (400 ft/sec) are allowed.

(5) Air-assisted flares shall be designed and operated with an exist velocity less than the velocity, V_{max}, as determined by the method specified in paragraph (f)(6).

(6) Flares used to comply with this section shall be steam-assisted, air-assisted, or nonassisted.

(d) Owners or operators of flares used to comply with the provisions of this subpart shall monitor these control devices to ensure that they are operated and maintained in conformance with their designs. Applicable subparts will provide provisions stating how owners or operators of flares shall monitor these control devices.

(e) Flares used to comply with provisions of this subpart shall be operated at all times when emissions may be vented to them.

(f) (1) Reference Method 22 shall be used to determine the compliance of flares with the visible emission provisions of this subpart. The observation period is 2 hours and shall be used according to Method 22.

(2) The presence of a flare pilot flame shall be monitored using a thermocouple or any other equivalent device to detect the presence of a flame.

(3) The net heating value of the gas being combusted in a flare shall be calculated using the following equation:

$$H_T = K \sum_{i=1}^{n} C_i H_i$$

where:

H_T = Net heating value of the sample, MJ/scm; where the net enthalpy per mole of offgas is based on combustion at 25 °C and 760 mm Hg, but the standard temperature for determining the volume corresponding to one mole is 20 °C;

$$K = \text{Constant, } 1.740 \times 10^{-7} \left(\frac{1}{\text{ppm}}\right) \left(\frac{\text{g mole}}{\text{scm}}\right) \left(\frac{\text{MJ}}{\text{kcal}}\right)$$

where the standard temperature for $\left(\frac{\text{g mole}}{\text{scm}}\right)$ is 20°C;

C_i = Concentration of sample component i in ppm on a wet basis, as measured for organics by Reference Method 18 and measured for hydrogen and carbon monoxide by ASTM D1946–77 (Incorporated by reference as specified in § 60.17); and

H_i = Net heat of combustion of sample component i, kcal/g mole at 25 °C and 760 mm Hg. The heats of combustion may be determined using ASTM D2382–76 (incorporated by reference as specified in § 60.17) if published values are not available or cannot be calculated.

(4) The actual exist velocity of a flare shall be determined by dividing the volumetric flowrate (in units of standard temperature and pressure), as determined by Reference Methods 2, 2A, 2C, or 2D as appropriate; by the unobstructed (free) cross sectional area of the flare tip.

(5) The maximum permitted velocity, V_{max}, for flares complying with paragraph (c)(4)(iii) shall be determined by the following equation.

$$\text{Log}_{10}(V_{max}) = (H_T + 28.8)/31.7$$

V_{max} = Maximum permitted velocity, M/sec
28.8 = Constant
31.7 = Constant
H_T = The net heating value as determined in paragraph (f)(3).

(6) The maximum permitted velocity, V_{max}, for air-assisted flares shall be determined by the following equation.

$$V_{max} = 8.706 + 0.7084\ (H_T)$$

V_{max} = Maximum permitted velocity, m/sec
8.706 = Constant
0.7084 = Constant
H_T = The net heating value as determined in paragraph (f)(3).

§ 60.482-10 [Amended]

3. By revising paragraph (d) of § 60.482-10 of Subpart VV of Part 61 as follows:

* * * * *

(d) Flares used to comply with this subpart shall comply with the requirements of §60.18.

* * * * *

§ 60.633 [Amended]

4. By revising paragraph (g) of § 60.633 of Subpart KKK as follows:

* * * * *

(g) Flares used to comply with this subpart shall comply with the requirements of § 60.18.

* * * * *

5. By revising paragraph (a)(38) and by adding paragraph (a)(46) of § 60.17 of Subpart A—General Provisions as follows:

§ 60.17 Incorporation by reference.

(a) * * *

(38) ASTM D2382-76, Heat of Combustion of Hydrocarbon Fuels by Bomb Calorimeter [High-Precision Method], IBR approved for § 60.18(f) and § 60.485(g).

* * * * *

(46) ASTM D1946-77, Analysis of Reformed Gas by Gas Chromatography, IBR approved for § 60.18(f).

* * * * *

PART 61—[AMENDED]

6. The authority citation for Part 61 continues to read as follows:

Authority: Secs. 101, 112, 114, 116, 301, Clean Air Act as amended (42 U.S.C. 7401, 7412, 7414, 7416, 7601).

§ 61.242-11 [Amended]

7. By revising paragraph (d) of § 61.242-11 of Subpart V of Part 61 as follows:

* * * * *

(d) Flares used to comply with this subpart shall comply with the requirements of § 60.18.

* * * * *

[FR Doc. 86-1063 Filed 1-17-86; 8:45 am]

BILLING CODE 6560-50-M

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40 CFR Part 180

[PP 4F3027/R766; FRL-2947-7]

Cyano(3-Phenoxyphenyl) Methyl-4-Chloro-Alpha-(1-Methylethyl) Benzeneacetate; Tolerances

Correction

In FR Doc. 85-30989 beginning on page 25 in the issue of Thursday, January 2, 1986, make the following correction:

On page 26, in the second column, the date line should read "December 20, 1985".

BILLING CODE 1505-01-M

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40 CFR Part 261

[FRL-2947-1]

Hazardous Waste Management System; Identification and Listing of Hazardous Waste

Correction

In FR Doc. 85-30890, beginning on page 53315 in the issue of Tuesday, December 31, 1985, make the following corrections on page 53319:

1. In the second column, § 261.31, fourteenth line from the bottom of the page, "1,2,2-" should read 1,1,2-".

2. In the third column, § 261.31, in the Hazard Code column of the table, the last entry "(T)" should read "(I,T)".

BILLING CODE 1505-01-M

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40 CFR Part 716

[OPTS-84017A; FRL-2945-4]

Submission of Lists and Copies of Health and Safety Studies on Vinyl Acetate

Correction

In FR Doc. 85-30719 beginning on page 52923 in the issue of Friday, December 27, 1985, make the following correction:

On page 52923, in the third column, in paragraph 2.a., in the first line, "Copy each" should read "copy of each".

BILLING CODE 1505-01-M

FEDERAL COMMUNICATIONS COMMISSION

47 CFR Parts 1 and 94

[FCC 86-8]

Private Operations-Fixed Microwave Service; Amendment

AGENCY: Federal Communications Commission.

ACTION: Final rule.

SUMMARY: The Commission has adopted an Order making various non-substantive amendments to Parts 1 and 94 of the Commission's Rules. These amendments pertain primarily to agency practice and procedure. This action will increase the public's understanding of the private microwave rules and reduce the number of improperly filed petitions and requests.

EFFECTIVE DATE: February 18, 1986.

ADDRESS: Federal Communications Commission, Washington, DC 20554.

FOR FURTHER INFORMATION CONTACT: Harold Salters, Land Mobile & Microwave Div., Private Radio Bureau, (202) 632-7597;

Mary Beth Hess, Rules Branch, Land Mobile & Microwave Div., Private Radio Bureau, (202) 634-2443.

SUPPLEMENTARY INFORMATION:

List of Subjects

47 CFR Part 1

Practice and procedure.

47 CFR Part 94

Radio.

Order

In the Matter of Amendment of Parts 1 and 94 of the Commission's Rules to make certain non-substantive changes.

Adopted: January 3, 1986.
Released: January 10, 1986.

By the Commission.

1. The Federal Communications Commission, on its own motion, is amending its rules governing Practice and Procedure (47 CFR Part 1) and the Private Operational-Fixed Microwave Service (47 CFR Part 94) by making certain editorial changes to clarify and correct several rule sections. These changes relate to agency practice and procedure and make other non-controversial amendments that will improve the usefulness of the rules to the public. The following subparagraphs explain these amendments which are fully set out in the attached Appendix:

(a) *Section 1.924 Assignment or transfer of control & § 94.27 Application*

APPENDIX "B"

FLARE STACKS INQUIRY PACKAGE
AS SUBMITTED TO
FLARE SYSTEM SUPPLIERS

FLARE STACKS
INQUIRY PACKAGE

1.0 Introduction
2.0 Information Requested
3.0 Flare Stack Requirements

ATTACHMENT I

Summary of Information 1 & 2
  Costs
  Technical

Summary of Information 3 & 4
  Costs
  Technical

Summary of Information 5
  Costs
  Technical

ATTACHMENT II

FLARES

1.0 General Requirements
2.0 Site Conditions & Codes
3.0 Composition & Character of Waste Gases
4.0 Schematics
  Fig. 4.1 Standard (Utility) Flare
  4.2 Smokeless Steam Injection Flare
  4.3 Smokeless Air Assist Flare
  4.4 Smokeless Multi Point Flare
  4.5 Smokeless Multi Point Staged Flare

INQUIRY PACKAGE

1.0 Introduction

Environment Canada is a department of the Federal Government of Canada representing the interest of maintaining quality of the environment.

On behalf of Environment Canada, SKM Consulting Ltd. (SKM) is preparing a report which will assess the present available and state of the art technology as related to the flaring of gases.

The study is primarily directed at the flaring of sour gases associated with the Petroleum and Natural Gas Industry in Canada.

The information presented in the report may be applied for the assessment of current regulations and their revision as may be desirable.

As a part of the work SKM is approaching selected vendors of relevant equipment to provide information regarding their expertise associated with "Flares".

SKM are requesting that information be supplied for alternate specific flare systems as outlined in the attachments hereto.

2.0 Information Requested (See Attachment I)

We request that information be provided as outlined below as may be applicable to the equipment which the vendor has available.

2.1 Costs

For Flare Stacks as contained in the attachments:

- All materials and equipment supplied F.O.B. point of manufacture to include all duties and taxes applicable to the F.O.B. point.
- To be preassembled to the maximum degree consistent with shipping by truck.
- Shipping and field installation to be provided by others including additional applicable federal and provincial taxes and duties.
- Costs to be broken down and presented in the manner outlined in Attachment I.
- Vendor is advised that this is not a "Request for Quotation" hence costs should be presented as "budget type" based upon his best information which is readily available.

2.2 Technical

Current technical information related to the above.

- Catalogue information.
- Outline dimension and weight of equipment items.
- Schematics of configuration.
- Information as listed in Attachment I.

Other

- Alternates which the vendor may deem to be practical and desirable.
- Other information which the vendor may feel is to his advantage in the promotion of his product.

2.3 Date

We would appreciate a reply by mid January 1987.

3.0 Flare Stack Requirements (See Attachment II)

The Flare Stack is to be installed at a typical sour gas processing plant located at a typical site in the Province of Alberta Canada.

For the purposes of this study, five stack arrangements have been selected for comparison; each arrangement has some alternates. We would be interested also in any other alternate which the vendor may deem to be desirable.

Arrangement	Alternates		
	O Without Velocity or Mol Seal	A With Velocity Seal Only	B With Density Seal Only
1. Standard or Utility	Base Case	✓	✓
2. Smokeless Steam Injection	---	✓	✓
3. Smokeless Air Assist	---	✓	---
4. Smokeless Multi Tip	---	✓	✓
5. Smokeless Multi Tip Staged	✓	---	---
6. Other Vendor Alternate			

The basic information required for design is supplied in Attachment II.

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (1 & 2)
COSTS

Stack Arrangement	1 Standard (Utility)			2 Smokeless Steam Injection	
Alternate	0 No Velocity Seal	A With Velocity Seal Only	B With Density Seal Only	A With Velocity Seal Only	B With Density Seal Only
Item					
Flare Burner	$	$	$	$	$
Seal		$	$	$	$
Stack	$	$	$	$	$
Guy Wires	$	$	$	$	$
Ladders & Platforms	$	$	$	$	$
Pilot Burners	$	$	$	$	$
Pilot Ignitors	$	$	$	$	$
Automatic Steam Control Station c/w Instrumentation (Packaged)				$	$
Misc. Piping & Hardware	$________	$________	$________	$________	$________
Total $ F.O.B. at Origin	$	$	$	$	$

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (1 & 2)
TECHNICAL

Stack Arrangement	1 Standard (Utility)			2 Smokeless Steam Injection	
Alternate	0 No Velocity Seal	A With Velocity Seal Only	B With Density Seal Only	A With Velocity Seal Only	B With Density Seal Only
Item					
Total Weight in Lbs.	✓	✓	✓	✓	✓
Fuel Gas					
Purge Rate					
min scf/d	✓	✓	✓	✓	✓
Pilot Gas					
min scf/d	✓	✓	✓	✓	✓
Steam					
lbs/hr				✓	✓
min press. psig				✓	✓
Ignitor Requirements					
Air Press. psig	✓	✓	✓	✓	✓
Rate scfm	✓	✓	✓	✓	✓
Electrical 110V Amps	✓	✓	✓	✓	✓
Soil Loadings (if available)					
Base lbs.	✓	✓	✓	✓	✓
Anchors lbs.	✓	✓	✓	✓	✓
Combustion Efficiency	✓	✓	✓	✓	✓
Destruction Efficiency	✓	✓	✓	✓	✓
NO_x emissions	✓	✓	✓	✓	✓
Noise Level at Base of Stack	✓	✓	✓	✓	✓
Waste Gas Pressure Drop from Base of Stack inches of H_2O	✓	✓	✓	✓	✓
or psi	✓	✓	✓	✓	✓

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (1 & 2)
TECHNICAL

Stack Arrangement	1 Standard (Utility)			2 Smokeless Steam Injection	
Alternate	0 No Velocity Seal	A With Velocity Seal Only	B With Density Seal Only	A With Velocity Seal Only	B With Density Seal Only
Item					
Internal Diameter - Stack	✓	✓	✓	✓	✓
Effective I.D. of burner	✓	✓	✓	✓	✓
Exit Velocity of Waste Gas fps.	✓	✓	✓	✓	✓
mach.	✓	✓	✓	✓	✓
Moving Parts Yes/No in waste gas stream	✓	✓	✓	✓	✓
Materials of Construction					
Burner	✓	✓	✓	✓	✓
Other	✓	✓	✓	✓	✓
Internal Refractory Yes/No	✓	✓	✓	✓	✓
External Refractory Yes/No	✓	✓	✓	✓	✓
Max. Distance Stack to Ignitor Ft.	✓	✓	✓	✓	✓
Max. Heat Intensity at ground level BTU/hr ft^2	✓	✓	✓	✓	✓

Other
Please add as may
be applicable

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (3 & 4)
COSTS

Stack Arrangement	3 Smokeless Air Assist	4 Smokeless Multi Point	
Alternate	A With Velocity Seal Only	A With Velocity Seal Only	B With Density Seal Only
Item			
Flare Burner	$	$	$
Seal	$	$	$
Stack	$ including air duct	$	$
Guy Wires	$	$	$
Ladders & Platforms	$	$	$
Pilot Burners	$	$	$
Pilot Ignitor	$	$	$
Air Blower & Motor	$		
Automatic Control Station for Air	$		
Misc. - Piping & Hardware	$	$	$
Total $ F.O.B. Origin	$	$	$

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (3 & 4)
TECHNICAL

Stack Arrangement	3 Smokeless Air Assist	4 Smokeless Multi Point	
Alternate	A With Velocity Seal Only	A With Velocity Seal Only	B With Density Seal Only
Item			
Total Weight lbs.	✓	✓	✓
Fuel Gas			
Purge Rate min scf/d	✓	✓	✓
Pilot Gas min scf/d	✓	✓	✓
Air Assist			
Quantity scf/m	✓		
Min. Press. inches H_2O	✓		
Ignitor Requirements			
Air Press. psig	✓	✓	✓
Rate scfm	✓	✓	✓
Electrical			
110V amps	✓	✓	✓
Electrical			
Blower HP	✓		
Soil Loadings (if available)			
Base lbs.	✓	✓	✓
Anchors lbs.	✓	✓	✓
Combustion Efficiency	✓	✓	✓
Destruction Efficiency	✓	✓	✓
NO_x Emissions	✓	✓	✓
Noise Level base of stack	✓	✓	✓
Waste Gas Pressure Drop			
from base of stack "H_2O	✓	✓	✓
or psi	✓	✓	✓
Internal Diameter Stack	✓	✓	✓
Effective I.D. of burner	✓	✓	✓
Exit Velocity of Waste Gas			
FPS	✓	✓	✓
mach.	✓	✓	✓

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (3 & 4)
TECHNICAL

Stack Arrangement	3 Smokeless Air Assist	4 Smokeless Multi Point	
Alternate	A With Velocity Seal Only	A With Velocity Seal Only	B With Density Seal Only
Item			
Moving Parts Yes/No In Waste Gas Stream	✓	✓	✓
Materials of Construction			
Burner	✓	✓	✓
Other	✓	✓	✓
Internal Refractory Yes/No	✓	✓	✓
External Refractory Yes/No	✓	✓	✓
Max. Distance Stack to Ignitor	✓	✓	✓
Max. Heat Intensity at ground level BTU/hr/ft^2	✓	✓	✓

Other
Please add as may be applicable

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (5)
COSTS

Stack Arrangements	5 Multi Point Staged
Flare Tips	$
Risers	$
Guy Wires	$
Ladders & Platforms	$
Pilot Burners	$
Pilot Ignitors	$
Stage Controls (Packaged)	$
Misc: Piping & Hardware	$
Total F.O.B. Origin	$

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (5)
TECHNICAL

Stack Arrangements	5 Multi Point Staged
Item	
Total Weight lbs.	✓
Fuel Gas	
Purge Rate	
Min. scfd	✓
Pilot Gas	
Min. scfd	✓
Ignitor Requirements	
Air Press. psig	✓
Rate scfm	✓
Electrical 110V amps	✓
Soil Loadings (if available)	
Base lbs	✓
Anchors lbs	✓
Combustion Efficiency	✓
Destruction Efficiency	✓
NO_x Emissions	✓
Noise Level at Base of Stack	✓
Waste Gas Pressure drop from base of Stack - inches of water	✓
or psi	✓
Exit Velocity of Waste Gas	
FPS	✓
Mach.	✓

ATTACHMENT I

FLARES
SUMMARY OF INFORMATION (5)
TECHNICAL

Stack Arrangements	5 Multi Point Staged
Item	
Moving Parts in Waste Gas Stream Yes/No	✓
Materials of Construction	
Burner	✓
Other	✓
Internal Refractory Yes/No	✓
External Refractory Yes/No	✓
Max. Distance Stack to Ignitor	✓
Max. Heat Intensity at Ground Level BTU/hr/ft^2	✓
Other Please add as may be applicable	

ATTACHMENT II

FLARES

1.0 General Requirements

The stacks shall be provided for the safe reliable, economical disposal of waste gas streams in a manner suitable to the authorities which have jurisdiction.

Generally as presented in the following parts:

2 - Site and Codes
3 - Composition and Character of Waste Gases
4 - Schematics
  .1 Standard (utility)
  .2 Smokeless Steam Injection
  .3 Smokeless Air Assist
  .4 Smokeless Multi Point
  .5 Smokeless Staged

2.0 Site Conditions and Codes

2.1 Site

General
- Province of Alberta Canada
- City of Red Deer Area

Elevation - Approximately 2800 ft. above sea level
Terrain - Rolling (Parkland)
Vegetation - Coniferous & Deciduous trees, 30 ft. maximum
some agricultural
mixed farming - cattle and hogs, wheat, oats, barley, hay, canola
Population - One family per section of land
Wind Speed - Gusts to 75 mph. (Structural)
- Heat Radiation Design 20 mph.
Temperature - Winter -35°F Summer 85°F
Moisture - 15 min. rain 3/4"
Annual precipitation - 17"
Snow Load - Ground snow load 31 lbs/ft^2
Earthquake - Zone 0 Acceleration Ratio, A = 0
Soils - Clay till
Assume allowable bearing load - 3 $tons/ft^2$
Access - Truck accessible, all weather road
Electrical - 440V 3 phase 60 cycle
Supply - 110V 1 phase 60 cycle
Classification - Group 1 Class D Div. 2
Steam Available - 35 psig
Air Available - 100 psig

2.2 Applicable Codes

- API RP 521 - Guide for Pressure - Relieving and Depressuring Systems
- National Building Code of Canada
- Government of Alberta, Electrical Code
- Refinery Piping Code ANSI B 31.3

2.3 Other

Minimum Allowable
Heat Content of Flared Gases Min. 9 Mj/m^3 (240 BTU/ft^3)

Max. allowable tree top level concentration SO_2
0.17 ppm, 1 hour, Alberta Dept. of Environment
Intermittent Flare Program

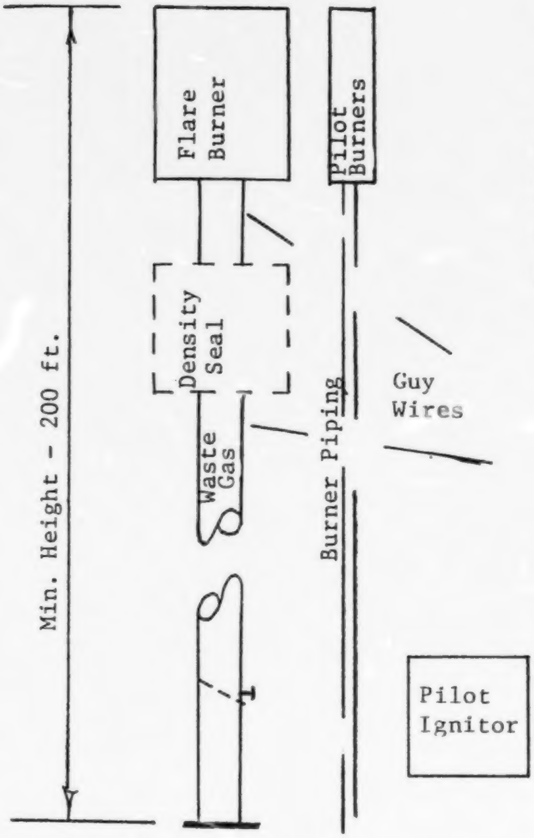
Max. allowable heat intensity at ground level
3000 $BTU/hr/ft^2$

Minimum Height of Stack - 200 feet
Based on flaring Stream 4 (Regenerator overhead acid gas)
Mingled with an appropriate amount of fuel gas whenever released to atmosphere

3.0 Composition and Character of Waste Gases

Stream Component	1 *Inlet* Separator Mol %	4 *Regenerator* Overhead Mol %	6 *Stabilizer* Overhead Mol %	10 *Sales Gas* Purge Gas Fuel Gas Mol %	14 *Stream* 4 Plus 185% Stream 10
H_2	--	--	--	--	--
H_e	--	--	--	--	--
N_2	3.00	--	tr	3.23	2.1
CO_2	1.80	46.62	1.24	--	16.35
H_2S	1.98	51.38	4.31	--	18.03
C_1	78.54	2.00	6.85	84.25	55.39
C_2	8.34		11.97	8.49	5.51
C_3	3.48		24.76	2.84	1.84
iC_4	0.52		10.73	0.33	0.22
nC_4	1.25		38.57	0.65	0.42
iC_5	0.35		1.39	0.11	0.07
nC_5	0.32		0.10	0.08	0.05
C_6	0.11			0.01	0.01
C_7^+ (MW = 100)	0.31			0.01	0.01
	100.00	100.00	100.00	100.00	100.00
MW	20.9	38.3	47.4	18.95	25.76
Sp. Gr.	0.722	1.32	1.64	0.655	0.89
Flared Quantity mmscfd/d (Add Stream 10 @ 185% to Stream 4)	350 87	13.5 3.4	19 5	)As required	38.5 9.6
	to be performed by others upstream of flare				√
Duration	1/2 hr 4 hrs	1 hr 4 hrs	2 hrs 4 hrs	)by design	1 hr 4 hrs
Frequency/annum	6 12	6 6	6 6	)	6 6
Pressure					
At Origin psig	1000	17	200	100 - 1000	17
Base of Stack Max psig	15 - 5	5	5	5	5
Temp at Base of stack °F	40	90	90	50	90
Smokeless up to Min. Rate mmscf/d	87	---	19	---	38.5
BTU					
LHV/mscf	1042	320	2395	1006	766
GHV/mscf	1150	348	2601	1112	844

4.1 SCHEMATIC OF STANDARD (UTILITY) FLARE


Min. Height - 200 ft.
Flare Burner
Pilot Burners
Density Seal
Waste Gas
Burner Piping
Guy Wires
Pilot Ignitor

Flare Burner

- Flame Retainer
- Windshield

Alternate

O - No Seals

A - With Velocity Seal Only

B - With Density Seal Only

Pilot Burners

- Three Required
- Windshields
- Non-retractable
- Thermocouple
- All Hardware to Grade

Pilot Ignitor

- Flame Front Generator
- Interconnecting Hardware to Stack by Others
- Sensing Alarm and Remote Point Connection

COMPONENTS OF STANDARD (UTILITY) FLARE (GUYED)

Require

Caged Ladder	- Yes
Platform	- Yes (2)
Aircraft Warning Lights	- No
Painting	- Yes - Aluminum
Painter Trolley	- No
Guy Wires	- Yes
Waste Gas Duct	- Yes
Flanged Connections	- Yes

FIGURE 4.1

4.2 SCHEMATIC OF SMOKELESS STEAM INJECTION FLARE

Flare Burner

- Flame Retainer
- Windshield

Steam Inject

- Ring & Nozzles
- All Hardware to Grade

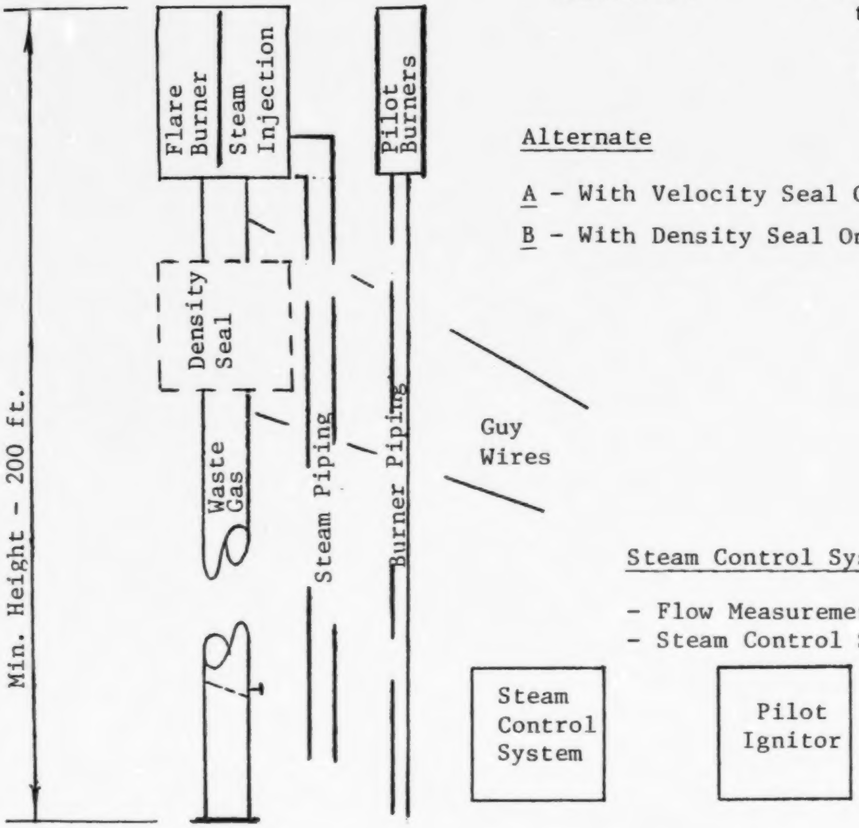
Pilot Burners

- Three Required
- Thermocouples
- All Hardware to Grade
- Windshields

Alternate

A - With Velocity Seal Only

B - With Density Seal Only


Min. Height - 200 ft.
Flare Burner
Steam Injection
Pilot Burners
Density Seal
Waste Gas
Steam Piping
Burner Piping
Guy Wires
Steam Control System
Pilot Ignitor

Steam Control System

- Flow Measurements
- Steam Control Station

Pilot Ignitor

- Flame Front Generator
- Interconnecting Hardware to Stack by Others
- Sensing Alarm and Remote Point Connection

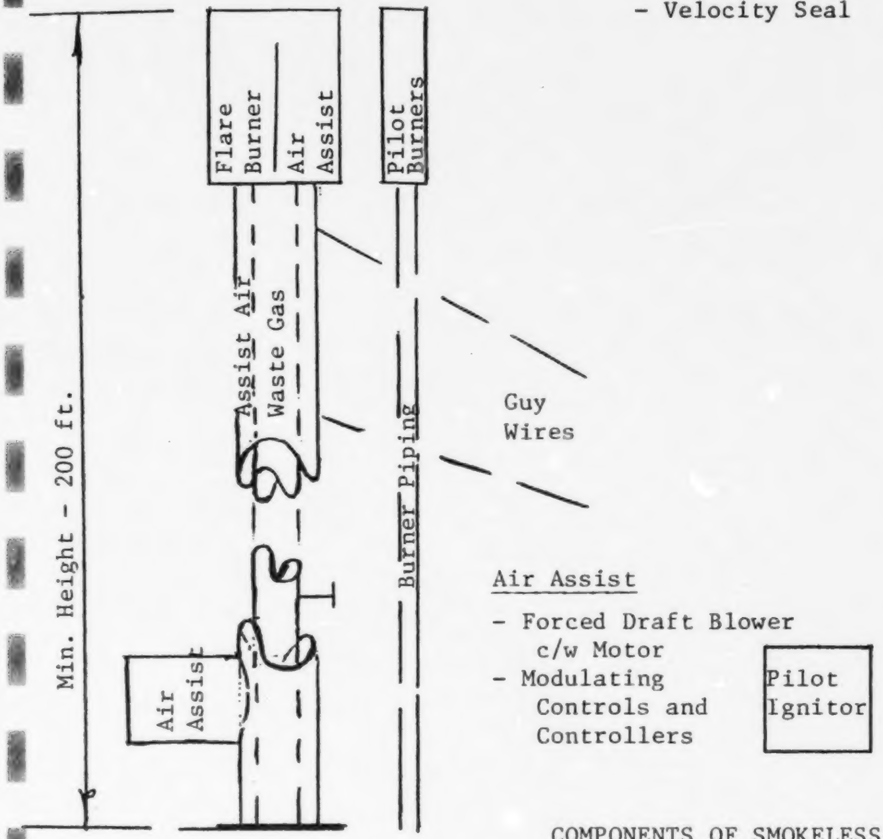
COMPONENTS OF SMOKELESS STEAM INJECTED FLARE (GUYED)

Require

Caged Ladder	- Yes
Platform	- Yes (2)
Aircraft Warning Lights	- No
Painting	- Yes - Aluminum
Painter Trolley	- No
Guy Wires	- Yes
Waste Gas Duct	- Yes
Flanged Connections	- Yes

FIGURE 4.2

4.3 SCHEMATIC OF SMOKELESS AIR ASSIST FLARE


Flare Burner
Air Assist
Pilot Burners
Assist Air
Waste Gas
Burner Piping
Guy Wires
Min. Height - 200 ft.
Air Assist
Pilot Ignitor

Flare Burner

- Flame Retainer
- Velocity Seal

Pilot Burner

- Three Required
- Windshields
- Thermocouples
- All Hardware to Grade

Pilot Ignitor

- Flame Front Generator
- Interconnecting Hardware to Stack by Others
- Sensing Alarm and Remote Point Connection

Air Assist

- Forced Draft Blower c/w Motor
- Modulating Controls and Controllers

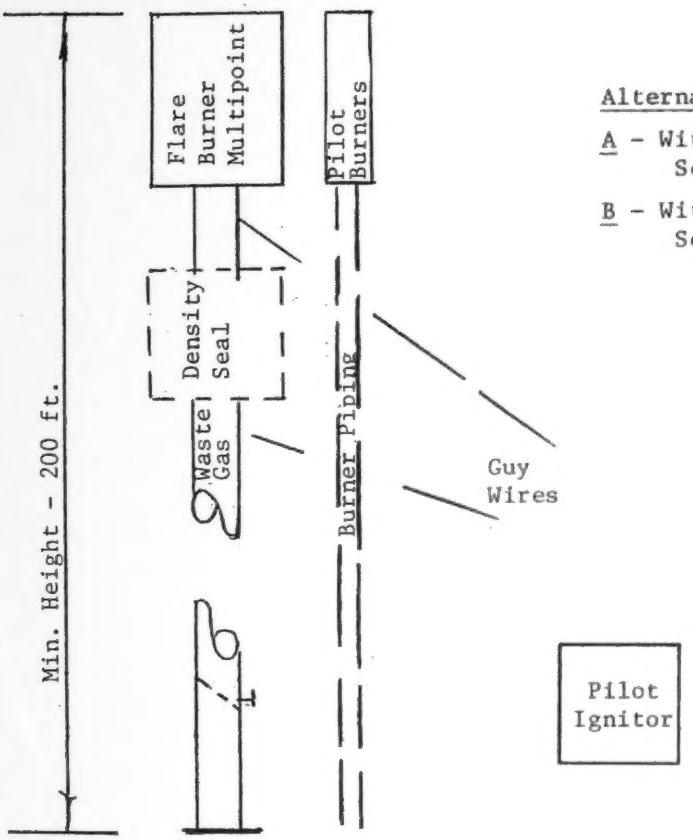
COMPONENTS OF SMOKELESS AIR ASSIST FLARE (GUYED)

Require

Caged Ladder	- Yes
Platform	- Yes (2)
Aircraft Warning Lights	- No
Painting	- Yes - Aluminum
Painter Trolley	- No
Guy Wires	- Yes
Waste Gas Duct	- Yes
Air Duct	- Yes
Flanged Connections	- Yes

FIGURE 4.3

4.4 SCHEMATIC OF SMOKELESS MULTIPOINT FLARE


Flare Burner Multipoint
Pilot Burners
Density Seal
Waste Gas
Burner Piping
Guy Wires
Min. Height - 200 ft.
Pilot Ignitor

Flare Burner

- Points (Divisions) by Vendor
- Detail by Vendor

Pilot Burner

- Number Required by Vendor
- Thermocouples
- All Hardware to Grade

Alternate

A - With Velocity Seal Only

B - With Density Seal Only

Pilot Ignitor

- Flame Front Generator
- Interconnecting Hardware to Stack by Others
- Sensing Alarm and Remote Point Connection

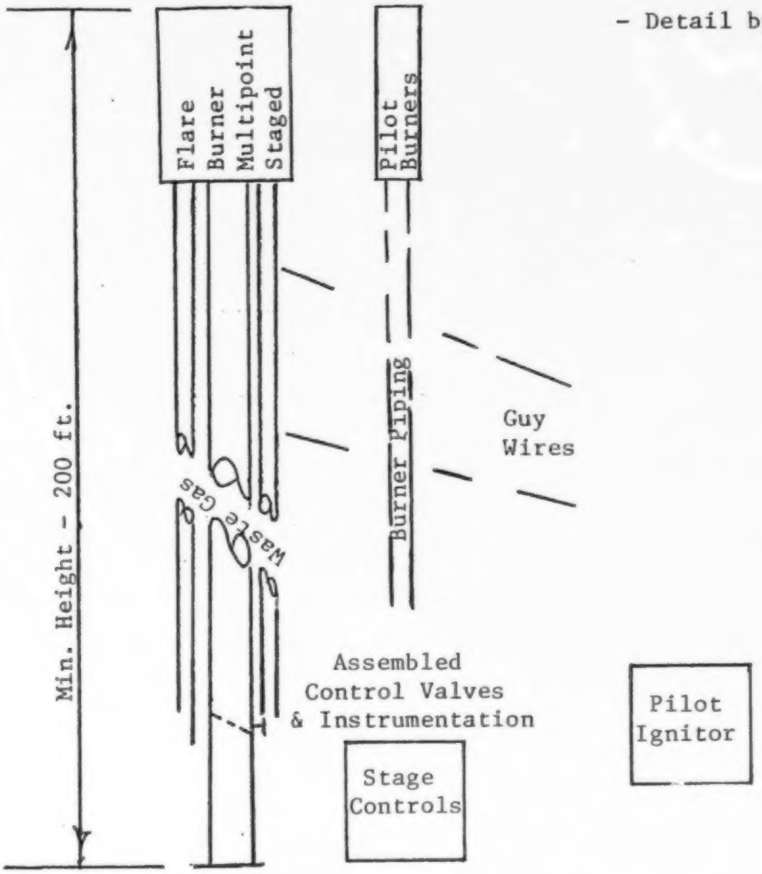
COMPONENTS OF SMOKELESS MULTIPOINT FLARE (GUYED)

Require

Caged Ladder	- Yes
Platform	- Yes (2)
Aircraft Warning Lights	- No
Painting	- Yes - Aluminum
Painter Trolley	- No
Guy Wires	- Yes
Waste Gas Duct	- Yes
Flanged Connections	- Yes

FIGURE 4.4

4.5 SCHEMATIC OF SMOKELESS MULTIPOINT STAGED FLARE


Flare Burner Multipoint Staged
Pilot Burners
Burner Piping
Guy Wires
Waste Gas
Min. Height - 200 ft.
Assembled Control Valves & Instrumentation
Stage Controls
Pilot Ignitor

Flare Burner

- Points by Vendor
- Detail by Vendor

Pilot Burners

- Number Required by Vendor
- Thermocouples
- All Hardware to Grade

Pilot Ignitor

- Flame Front Generator
- Interconnecting Hardware to Stack by Others
- Sensing Alarm and Remote Point Connection

COMPONENTS OF SMOKELESS MULTIPOINT STAGED FLARE (GUYED)

Require

Caged Ladder - Yes
Platform - Yes (2)
Aircraft Warning Lights - No
Painting - Yes - Aluminum
Painter Trolley - No
Guy Wires - Yes
Waste Gas Risers - Yes
Flanged Connections - Yes

FIGURE 4.5

APPENDIX "C"

REVIEW AND ASSESSMENT
OF
CURRENT FLARING TECHNOLOGY

TERMS OF REFERENCE

REVIEW AND ASSESSMENT OF CURRENT FLARING TECHNOLOGY

Terms of Reference

1. A review shall be provided that discusses the following in detail:

   - types of flares, (i.e. ground, elevated, emergency, continuous, air assisted and/or steam assisted);

   - design features, (i.e. shrouds, venturi, tip, knockout drums, seal systems, flame arresters, etc.);

   - ignition systems, (i.e. manual, electric, electronic, flame front, arcing, automatic);

   - flare failure detection and interconnecting alarms and shutdown systems,

   - flare volumetric gas flow rate measurement and recording including methods of sampling for gas composition or heating value,

   - design rationale and design criteria such as dispersion, exit velocity, heating value, noise, thermal radiation, smoke, odour, safety, combustion and destruction efficiencies, spacing and design of multipoint tips, flare heads, knockout drums, etc.,

   - approximate comparative costs of various flaring systems for three sizes referred to as small, medium and large flares. The cost factors should include equipment and installation costs, energy useage costs, maintenance, controls, interconnecting accessories, and any other significant cost items,

   - any other limitations of equipment/systems to flaring operations or added advantages of pollution abatement such as NOx control, odour control, higher thermal lift, etc. if applicable, and

   - performance of equipment in terms of expected and actual output over their life span.

2. Available flaring equipment shall be described for each industry sector and in terms of range of suppliers. Product description shall include critical parameters such as those mentioned in 1.

3. Recently developed and/or emerging technologies in the research and/or demonstration stage shall be reviewed outlining cost benefit scenarios, improvement over existing equipment, expected and/or demonstrated level of performance, and specific industrial applications.

4. Current regulatory practice in Alberta and other jurisdictions such as US EPA, California, Texas and Oklahoma, Canada, U.K. and West Germany shall be described. This description should include existing regulations/guidelines pertaining to flare licensing and performance criteria to meet specific requirements of the legislation.

5. An assessment of various flaring technologies in the context of existing and upcoming legislation shall be conducted. This assessment should include a comparison of different flare manufacturer's equipment in terms of performance, costs, reliability, ease of operation, limitations and/or benefits. This assessment should be repeated for each of the industrial sectors outlined in Objectives and Scope. In assessing flare equipment, consideration should also be given to the quality and type of upstream equipment, which might affect ultimate flare performance.

6. The contractor shall summarize findings in a clear and precise report written in accordance with the specifications attached as Annex "A", and be acceptable to Environment Canada.

7. Twenty-five copies of the draft report will be provided to the Scientific Authority by February 2, 1987.

8. Seventy-five copies of the final report will be provided by the contractor within one month of receiving written comments and revisions to the draft report from Environment Canada.